TRENDS IN INTERNATIONAL MATHEMATICS AND SCIENCE STUDY

TIMSS

TIMSS 2007 Assessment Frameworks

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International Association
for the Evaluation of
Educational Achievement

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Foreword

The International Association for the Evaluation of Educational Achievement (IEA) founded in 1959 has, over the past 45 years, conducted comparative research studies focusing on educational policies, practices, and outcomes in more than 60 countries around the world. Organized around a Secretariat located in Amsterdam, The Netherlands, and a data processing center in Hamburg, Germany, IEA, through its various projects, continues to report on a wide range of topics and subject matters. IEA's focus on curriculum and what students have learned in school within a given time frame has allowed it to contribute to a deep understanding of the educational processes both within individual countries as well as within the broader international context.

TIMSS, IEA's Trends in International Mathematics and Science Study, conducts international comparisons of student achievement in mathematics and science on a regular four-year cycle. Directed by the TIMSS & PIRLS International Study Center at Boston College, TIMSS also collects a rich array of information about the school and home contexts for learning mathematics and science. With data collection for the first time in 1995, and again in 1999 and 2003, the TIMSS data collection in 2007 will provide trend data on students' mathematics and science achievement at four points in time extending over a 12-year period. Countries that have participated in successive waves of TIMSS have access to unparalleled information about the improvement or decline in the mathematics and science achievement of their students. Central to the success of TIMSS has been participating countries' expertise in the areas of curriculum, measurement, and education, and their willingness to work together in the interests of improving mathematics and science education.

The TIMSS 2007 Assessment Frameworks provides a template for IEA's work in the assessment of Mathematics and Science at fourth and eighth grades. Building on the frameworks prepared for the 2003 assessment, this document is the product of an extensive collaborative process involving many individuals and expert groups from around the world, most notably the TIMSS advisory groups in mathematics and science, the National Research Coordinators (NRCs) from more than 60 countries, and TIMSS staff at Boston College, Amsterdam, and Hamburg. The review process of consultation, collaboration and systematic review among representatives of the TIMSS countries, the mathematics and science research community, and other experts ensures that the document reflects the latest advances in thinking about large-scale comparative assessment of mathematics and science and embodies the interests of many individuals and countries around the world.

Any project as ambitious as TIMSS 2007 requires significant financial support for its development and execution. Support for this project and the development of the framework document was provided by the National Center for Education Statistics of the US Department of Education, the US National Science Foundation, the World Bank, the United Nations Development Programmme, and the participating countries. IEA is extremely grateful for their continued support. We are grateful also for the generous support provided for TIMSS by Boston College and the National Foundation for Educational Research for England and Wales.

The work presented in this document represents the efforts of many individuals and groups. TIMSS derives the direction and leadership necessary to complete such a complex and ambitious project from IEA's TIMSS & PIRLS International Study Center in the Lynch School of Education at Boston College. Together with the committed and able staff from the consortium of organizations that work to implement TIMSS, the Center's dedicated staff and consultants have played a vital role in developing the assessment frameworks. Crucial also has been the work of the TIMSS advisory groups in mathematics and science, and in particular that of TIMSS Mathematics Coordinator Graham Ruddock and TIMSS Science Coordinator Christine O'Sullivan. Taking special responsibility for mathematics and science, respectively, Alka Arora and Ebru Erberber each made major contributions to the frameworks document. Eugene Johnson and Pierre Foy adapted the TIMSS assessment design to the requirements of the 2007 assessment. All of the Boston College staff, and in the particular the TIMSS International Study Directors, Ina V.S. Mullis and Michael O. Martin of Boston College, have been central to the preparation of this document. To all of them I would like to express our sincere thanks.

Hans Wagemaker

Executive Director, IEA

Introduction

Overview of TIMSS

IEA's Trends in International Mathematics and Science Study (TIMSS) provides information to improve teaching and learning in mathematics and science. TIMSS assesses achievement in mathematics and science at the fourth and eighth grades and collects a rich array of background information to address concerns about school resources and the quality of curriculum and instruction. Conducted every four years on a regular cycle, TIMSS provides countries with an unprecedented opportunity to measure progress in educational achievement in mathematics and science.

As a project of the International Association for the Evaluation of Educational Achievement (IEA), TIMSS has the benefit of drawing on the cooperative expertise provided by representatives from countries all around the world. The IEA is an independent international cooperative of national research institutions and government agencies that has been conducting studies of cross-national achievement since 1959. As of 2005, IEA had 62 institutional members.

TIMSS 2007 is the most recent in the series of IEA studies to measure trends in students' mathematics and science achievement. The first cycle of TIMSS was in 1995 in 41 countries. The second cycle in 1999 involved 38 countries (26 were able to measure trends). Continuing the regular cycle of studies at four-year intervals, TIMSS 2003 involved more than 50 countries and approximately 60 countries are expected to participate in TIMSS 2007. Nearly 40 of these countries will have trend data, some covering more than a decade back to 1995.

Additionally, to provide each participating country with an extensive resource for interpreting the results and to track changes in curriculum and instructional practices, TIMSS asks students, their teachers, and their school principals to complete questionnaires about the contexts for learning mathematics and science. TIMSS also collects detailed information about the mathematics and science curricula in each country. Trend data from these questionnaires provide a dynamic picture of changes in the implementation of educational policies and practices and help to raise new issues relevant to improvement efforts.

TIMSS data have had an enduring impact on reform and development efforts in mathematics and science education around the world, leading on one hand to continuing demand for trend data to monitor development and on the other to a need for more and better policy-relevant information to guide and evaluate new initiatives.

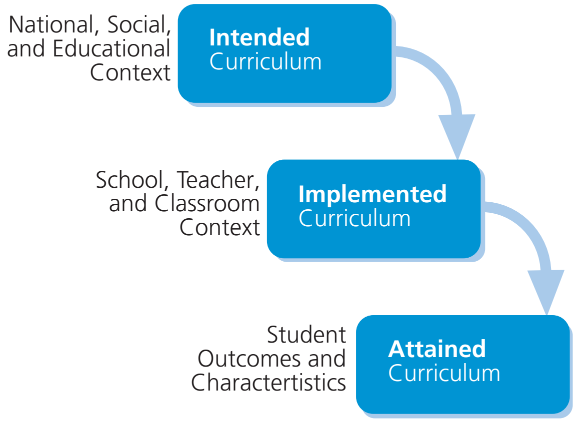
The TIMSS 2007 Assessment Frameworks

This publication, the *TIMSS 2007 Assessment Frameworks*, contains three frameworks and explains the assessment design that will serve as the basis for implementing TIMSS 2007. The Mathematics Framework and the Science Framework in Chapters 1 and 2, respectively, describe in some detail the major content and cognitive domains in mathematics and science to be tested at the fourth and eighth grades. The content domains and topic areas are described separately for the fourth and eighth grades with each topic area elaborated with specific objectives. Within mathematics and science, the cognitive domains are parallel across grades, but with different levels of emphasis. The Contextual Framework in Chapter 3 describes the types of factors and contexts associated with students' learning in mathematics and science that will be investigated via the questionnaires. Finally, Chapter 4 provides an overview of the Assessment Design, including general parameters for item development.

The TIMSS Curriculum Model

Building on earlier IEA studies of mathematics and science achievement, 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 achieved curriculum (see Exhibit 1). These represent, respectively, the mathematics and science that society intends for students to learn and how the education system should be organized to facilitate this learning; what is actually taught in classrooms, who teaches it, and how it is taught; and, finally, what it is that students have learned, and what they think about these subjects.

Exhibit 1: TIMSS Curriculum Model



Working from this model, TIMSS uses mathematics and science achievement tests to describe student learning in the participating countries, together with questionnaires to provide a wealth of information. The questionnaires ask about the structure and content of the intended curriculum in mathematics and science, the preparation, experience, and attitudes of teachers, the mathematics and science content actually taught, the instructional approaches used, the organization and resources of schools and classrooms, and the experiences and attitudes of the students in the schools.

The Development Process for the TIMSS 2007 Assessment Frameworks

The TIMSS Assessment Frameworks for 2007 rely heavily on the extensive effort expended to update the frameworks for TIMSS 2003. For TIMSS 2003, the TIMSS & PIRLS International Study Center engaged in a lengthy and intensive process to update the frameworks used in 1995 and 1999. Supported by the U.S. National Science Foundation, this process involved widespread participation and reviews by educators around the world to ensure the frameworks were appropriate for the many TIMSS countries. To permit the content assessed by TIMSS to evolve, the frameworks used in the 1990s were revised to reflect changes during the last decade in curricula and the way mathematics and science are taught. In particular, for the first time, the Mathematics and Science Frameworks were expanded to provide specific objectives for assessing students at the fourth and eighth grades.

An international panel of mathematics and science education and testing experts provided guidance for the general form the assessment frameworks should take and representatives from national centers in the participating countries were asked to play an important role in contributing critiques and advice as the frameworks were developed. Using an iterative process, successive drafts were presented for comment and review by the TIMSS 2003 National Research Coordinators (NRCs), national committees within participating countries, and expert panel members.

The participating countries completed detailed questionnaires, providing valuable feedback about the topics included in their curricula and the suitability and desirability of assessing particular topics at the fourth and eighth grades. As such, the frameworks do not consist solely of content and behaviors included in the curricula of all participating countries. The aim of the thorough consultation on curriculum within countries was to ensure that goals of mathematics and science education regarded as important in a significant number of countries were included.

Beginning with TIMSS 2007, IEA and the TIMSS & PIRLS International Study Center have decided to update the TIMSS Assessment Frameworks with every cycle. Updating the frameworks regularly provides participating countries greater opportunity to review and provide information about the frameworks and results in more coherence from assessment to assessment, permitting the frameworks, the instruments, and the procedures to evolve gradually into the future.

For TIMSS 2007, the frameworks were discussed by the NRCs at their first meeting. Participating countries also consulted with their national experts and responded to questionnaires about the possibility of combining some content areas receiving low priority in previous assessments to improve the potential for measuring trends over time in content areas. The questionnaires also attempted to garner each country's views about adding or deleting particular assessment topic areas and objectives. Revised on the basis of input from the participating countries, the frameworks were reviewed in-depth by the TIMSS 2007 Science and Mathematics Item Review Committee (SMIRC). Using an iterative process, the frameworks as further revised by SMIRC were once again reviewed by the NRCs and updated finally prior to publication.

The *TIMSS 2007 Assessment Frameworks* document closely resembles that for TIMSS 2003. Since it is crucial to have continuity in a study designed to measure trends in educational achievement over time, this is very appropriate. However, there are some notable revisions. In the Mathematics and Science Frameworks, the content domains are presented separately for the fourth and eighth grades, and there has been a concerted effort to better reflect fourth-grade curricula. At both grades, there was an effort to consolidate the major content areas and adjust the assessment topic areas and objectives to make them more appropriate and feasible in the context of a large-scale international assessment.

The cognitive domains in the Mathematics and Science Frameworks also have been revised for TIMSS 2007. To increase the potential for analyzing and reporting the mathematics and science results according to cognitive domains, the U.S. National Center for Education Statistics provided support to examine and refine the mathematics cognitive domains used in TIMSS 2003. The issue of reporting results for cognitive domains in both mathematics and science was discussed by the NRCs, and the SMIRC mathematics and science experts worked to recast the cognitive domains in mathematics and science, respectively, to develop a classification scheme that encompassed the important cognitive domains assessed by TIMSS while sharpening the distinction among mutually exclusive categories. These revisions were reviewed by the TIMSS 2007 NRCs in parallel with the updates to the content domains.

The Contextual Framework for TIMSS 2007 has changed little from TIMSS 2003, being modified simply to reflect updates to the TIMSS questionnaires given to students, their teachers, and their principles as well as the questionnaires completed by countries about the topics covered in their intended curricula. The Assessment Design, however, has been modified to ensure that students have ample response time and to have a more straightforward booklet design.

In the discussions about updating the frameworks held by the NRCs and the SMIRC as well as by the IEA and TIMSS management and technical groups, the emphasis has been on improving the quality of measurement in the assessments for TIMSS 2007 and on increasing the utility of results for participating countries. This includes assessing content appropriate to the students and important to their future lives, ensuring adequate response time for students, increasing operational feasibility, and maximizing the potential to improve reporting achievement in the content and cognitive domains assessed.

More About TIMSS[1]

To be particularly relevant to decision-making and implementing school policy, TIMSS assesses students at two important educational milestones – at the end of four years of formal schooling (end of primary school) and the end of eight years of formal schooling (end of lower-secondary education). Because TIMSS studies the effectiveness of curriculum and instruction in relation to student achievement, it is important for TIMSS to assess mathematics and science achievement at the same point in schooling across countries. That is, for fair comparisons, students should have had the opportunity to learn mathematics and science for an equivalent number of years of formal schooling.

TIMSS data complement IEA's Progress in International Reading Literacy Study (PIRLS) conducted at the fourth grade. By participating in TIMSS and PIRLS, countries can have information at regular intervals about how well their students read and what they know and can do in mathematics and science. TIMSS also complements the OECD's Programme for International Student Achievement (PISA), which assesses the mathematics, science, and reading literacy of 15-year-olds.

With each cycle, TIMSS releases test questions to the public and then replaces these with newly developed questions. To develop the

1 For detailed information about TIMSS, please see the TIMSS websites: timss.bc.edu and www.iea.nl. Also, see the *TIMSS 2003 International Mathematics Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades*. Mullis, I.V.S., Martin, M.O., Gonzalez, E.J., & Chrostowski, S.J. (2004) Chestnut Hill, MA: Boston College and the *TIMSS 2003 International Science Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades*. Martin, M.O., Mullis, I.V.S., Gonzalez, E.J., & Chrostowski, S.J. (2004). Chestnut Hill, MA: Boston College.

new questions, the TIMSS & PIRLS International Study Center works with representatives from the participating countries to develop items that measure objectives in the frameworks and adhere to the TIMSS guidelines. The items then undergo an extensive review process involving numerous experts in education, mathematics, science, and measurement, including the SMIRC and the NRCs. The items are field tested in each of the participating countries and then reviewed again by SMIRC and the NRCs prior to selection for data collection.

The tests contain questions asking students to select appropriate responses or to solve problems and answer questions in formats requiring them to construct their own answers. Beginning in TIMSS 2003, an effort was made to place more emphasis on questions and tasks that offer better insight into students' analytical, problem-solving, and inquiry skills and capabilities. Subsequent to instrument development and production, TIMSS is administered to representative samples of students in the participating countries. An enormous amount of energy is devoted to ensuring high quality data. Attention is given to meeting rigorous standards every step of the way through sampling, translation verification, instrument production, test administration, scoring, database construction and documentation, analysis, scaling, reporting, technical documentation, dissemination of the database, and training in how to use the data for secondary analyses.

TIMSS is a major undertaking of the IEA, and together with PIRLS, comprises the core of IEA's regular cycles of studies. IEA has entrusted responsibility for the overall direction and management of the project to its TIMSS & PIRLS International Study Center at Boston College. In carrying out TIMSS, the TIMSS & PIRLS International Study Center works closely with the IEA Secretariat in Amsterdam on country membership and translations verification, the IEA Data Processing Center in Hamburg on database creation and documentation, Statistics Canada in Ottawa on sampling, and Educational Testing Service in Princeton, New Jersey on the psychometric scaling of the data.

What is the value of TIMSS?

TIMSS helps countries monitor and evaluate their mathematics and science teaching across time and across grades. By participating in TIMSS, countries can:

- Have comprehensive and internationally comparable data about what mathematics and science concepts, processes, and attitudes students have learned by the fourth and eighth grades.
- Assess progress internationally in mathematics and science learning across time for students at the fourth grade and for students at the eighth grade.
- Identify aspects of growth in mathematical and scientific knowledge and skills from fourth grade to eighth grade.
- Monitor the relative effectiveness of teaching and learning at the fourth as compared to the eighth grade, since the cohort of fourth-grade students is assessed again as eighth graders.
- Understand the contexts in which students learn best. TIMSS enables international comparisons among the key policy variables in curriculum, instruction, and resources that result in higher levels of student achievement.
- Use TIMSS to address internal policy issues. Within countries, for example, TIMSS provides an opportunity to examine the performance of population subgroups and address equity concerns. It is efficient for countries to add questions of national importance (national options) as part of their data collection effort.

Chapter One
TIMSS 2007 Mathematics Framework

Overview

Students should be educated to recognize mathematics as an immense achievement of humanity, and to appreciate its nature. Nevertheless, learning mathematics for its own sake is probably not the most compelling reason for universal inclusion of mathematics in school curricula. Prime reasons for having mathematics as a fundamental part of schooling include the increasing awareness that effectiveness as a citizen and success in a workplace are greatly enhanced by knowing and, more important, being able to use mathematics. The number of vocations that demand a high level of proficiency in the use of mathematics, or mathematical modes of thinking, has burgeoned with the advance of technology, and with modern management methods.

This chapter contains the framework for the TIMSS 2007 mathematics assessments at the fourth and eighth grades. At both grades, the mathematics assessment framework for TIMSS 2007 is organized around two dimensions, a content dimension specifying the domains or subject matter to be assessed within mathematics (for example, number, algebra, geometry, and data and chance at the eighth grade) and a cognitive dimension specifying the domains or thinking processes to be assessed (that is, knowing, applying, and reasoning). The cognitive domains describe the sets of behaviors expected of students as they engage with the mathematics content.

The content and cognitive domains are the foundation of the TIMSS 2007 fourth- and eighth-grade assessments. The content domains differ for the fourth and eighth grades, reflecting the nature and difficulty of the 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 geometry and algebra, but since geometry and algebra generally are not taught as a formal subjects in primary school, the domain assessed at the fourth grade focuses on geometric shapes and measures and introductory algebra concepts are included as part of number. At the fourth grade, the domain pertaining to data focuses on reading and displaying data whereas at eighth grade it includes more emphasis on interpretation of data and the fundamentals of probability (called "chance").

The cognitive domains are the same for both grades, encompassing a range of cognitive processes involved in working mathematically and solving problems right through the primary and middle school years.

Exhibit 2 shows the target percentages of testing time devoted to each content and cognitive domain for both the fourth- and eighth-grade assessments.

Exhibit 2: Target percentages of the TIMSS 2007 Mathematics Assessment Devoted to Content and Cognitive Domains at Fourth and Eighth Grades

Fourth-Grade Content Domains	Percentages
Number	50%
Geometric Shapes and Measures	35%
Data Display	15%
Eighth-Grade Content Domains	**Percentages**
Number	30%
Algebra	30%
Geometry	20%
Data and Chance	20%

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

Each content domain has several topic areas (i.e., *number* at eighth grade is further categorized by whole numbers; fractions and decimals; integers; and ratio, proportion, and percent). Each topic area is presented as a list of objectives covered in many participating countries, at either fourth grade or eighth grade as appropriate.

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

Mathematics Content Domains – Fourth Grade

The content domains described in the mathematics framework for the fourth grade and the target percentages of testing time devoted to each are shown below in Exhibit 3.

Exhibit 3: Target Percentages of the TIMSS 2007 Mathematics Assessment Devoted to Content Domains at Fourth Grade

Fourth-Grade Content Domains	Percentages
Number	50%
Geometric Shapes and Measures	35%
Data Display	15%

The content domains define the specific mathematics subject matter covered by the TIMSS 2007 assessment at fourth grade. Each content domain has several topic areas; each one is presented as a list of objectives covered in the mathematics curriculum in the majority of participating countries. These grade specific objectives are written in terms of student understandings or abilities that items aligned with these objectives are designed to elicit. The following sections describe each of the mathematics content domains at fourth grade.

Number

The *number* content domain for the fourth grade includes understanding of place value, ways of representing numbers, and the relationships between numbers. At the fourth grade, students should have developed number sense and computational fluency, understand the meanings of operations and how they relate to one another, and be able to use numbers and operations (i.e. add, subtract, multiply, and divide) to solve problems. They should be familiar with a range of number patterns, exploring the relationships between the numbers which are in the pattern or are used to derive it.

The number content domain consists of understandings and skills related to four topic areas:

- Whole numbers
- Fractions and decimals
- Number sentences
- Patterns and relationships

Since whole numbers provide the easiest introduction to operations with numbers that are basic to the development of mathematics, working with whole numbers is the foundation of mathematics in the primary school. The TIMSS 2007 content framework reflects this. Most children learn to count at a young age and can solve simple addition, subtraction, multiplication, and division problems during the first few years of school. Fourth-grade students should be able to compute with whole numbers of reasonable size, estimate sums, differences, products, and quotients, and use computation to solve problems.

Students also should be using their grasp of number to understand the relationships between units of measurement and to convert from one unit to another. Such relationships should include the multiples of 10 found in the metric system of measurement and other familiar ones such as the relationships between seconds, minutes, hours and days.

At the fourth grade, pre-algebraic concepts and skills are also part of the TIMSS assessment. The focus is on the type of understanding, which is built upon later to develop more formal, algebraic thinking. Understandings related to simple equations – in the form of number sentences – and to number patterns are included.

Students should be working with number sentences and finding missing numbers in them, working towards the idea of finding a value for an unknown, and using number sentences to model simple situations involving one of the four operations. They should be exploring number patterns, investigating the relationships between their terms and the finding or using the rules that generate them.

In the area of common fractions and decimal fractions, the emphasis is on representation of fractions and understanding what quantities the symbols represent. At the fourth grade, students should be able to compare familiar fractions and decimals.

Number: Whole Numbers

1. Represent whole numbers using words, diagrams, or symbols.
2. Demonstrate knowledge of place value, including recognizing and writing numbers in expanded form.
3. Compare and order whole numbers.
4. Know the four operations (+, −, ×, ÷) and compute with whole numbers.
5. Recognize multiples and factors of numbers; read weight and temperature scales marked in multiples.
6. Estimate computations by approximating the numbers involved.
7. Solve problems, including those set in real life contexts (for example, measurement and money problems).
8. Solve problems involving proportions.

Number: Fractions and Decimals

1. Recognize fractions as parts of unit wholes, parts of a collection, locations on number lines, and divisions of whole numbers.
2. Represent fractions using words, numbers, or models.
3. Identify equivalent fractions; compare and order fractions.
4. Add and subtract simple fractions.
5. Show understanding of decimal place value including recognizing and writing decimals using words and numbers.
6. Add and subtract decimals.
7. Solve problems involving simple fractions or decimals.

Note: Fourth-grade fractions items will involve denominators of 2, 3, 4, 5, 8, or 10. Fourth-grade decimals items will involve decimals to tenths and/or hundredths.

Number: Number Sentences with Whole Numbers

1. Find the missing number or operation in a number sentence (e.g., if 17 + __ = 29, what number would go in the blank to make the number sentence true?).
2. Model simple situations involving unknowns with expressions or number sentences.

Number: Patterns and Relationships

1. Extend patterns and find missing terms in them.
2. Describe relationships between adjacent terms in a sequence or between the sequence number of the term and the term.
3. Generate pairs of whole numbers following a given rule (e.g., multiply the first number by 3 and add 2 to get the second number).
4. Write or select a rule for a relationship given some pairs of whole numbers satisfying the relationship.

Geometric Shapes and Measures

The *geometric shapes and measures* domain includes properties of geometrical figures such as lengths of sides, sizes of angles, areas, and volumes. Students should be able to identify and analyze the properties and characteristics of lines, angles, and a variety of geometric figures, including two- and three-dimensional shapes, and to provide explanations based on geometric relationships. This domain includes understanding informal coordinate systems and using spatial visualization skills to relate between two- and three-dimensional representations of the same shape.

The three topic areas in geometric shapes and measures are:

- Lines and angles
- Two- and three-dimensional shapes
- Location and movement

Spatial sense is integral to the study and assessment of geometry. At the fourth grade, students will be asked to describe, visualize, and draw a variety of geometric figures, including angles, lines, triangles, quadrilaterals, and other polygons. Students should be able to make and decompose compound shapes. They should be able to recognize line symmetry, draw symmetrical figures, and describe rotations and reflections.

At the fourth grade, appropriate performances expected of students include the use of instruments and tools to measure physical attributes, including length, area, volume, and angle. Knowledge about which units to use in particular contexts should underly their measurement skills. Students at this grade are also expected to use approximation and estimation, and simple formulas, to calculate areas and perimeters of squares and rectangles.

Geometric Shapes and Measures: Lines and Angles

1. Measure and estimate lengths.
2. Identify and draw parallel and perpendicular lines.
3. Compare angles by size and draw angles (e.g., a right angle, angles larger or smaller than a right angle).

Geometric Shapes and Measures: Two- and Three-dimensional Shapes

1. Identify common geometric shapes.
2. Know, describe, and use elementary properties of geometric figures.
3. Classify and compare geometric figures, (e.g., by shape, size or properties).
4. Recognize relationships between three-dimensional shapes and their two-dimensional representations.
5. Calculate areas and perimeters of squares and rectangles of given dimensions
6. Determine and estimate areas and volumes (e.g., by covering with a given shape or by recognizing that area is conserved).

Geometric Shapes and Measures: Location and Movement

1. Use informal coordinate systems to locate points in a plane.
2. Recognize and draw figures with line symmetry.
3. Recognize and draw reflections and rotations of figures.

Data Display

The *data display* content domain includes reading and interpreting displays of data. It also includes understanding how to organize data that have been collected and how to display it in graphs and charts that will be useful in answering the questions that prompted the data collection. Students should be able to compare characteristics of data and to draw conclusions based on data displays.

The data content domain consists of the following major topic areas:

- Reading and interpreting
- Organizing and representing

At the fourth grade, students should be able to read various data displays. Students also can engage in simple data-gathering plans or work with data that have been gathered by others. They should be developing skills in representing data and recognizing a variety of forms of data display.

Data Display: Reading and Interpreting

1. Read data from tables, pictographs, bar graphs, and pie charts.
2. Compare information from related data sets (e.g., given data or representations of data on the favorite flavors of ice cream in four or more classes, identify the class with chocolate as the most popular flavor).
3. Use information from data displays to answer questions that go beyond directly reading the data displayed (e.g., combine data, perform computations based on the data, draw conclusions, and make predictions).

Data Display: Organizing and Representing

1. Compare and match different representations of the same data.
2. Organize and display data using tables, pictographs, and bar graphs.

Mathematics Content Domains – Eighth Grade

The content domains described in the mathematics framework for the eighth grade and the target percentages of testing time devoted to each are shown below in Exhibit 4.

Exhibit 4: Target Percentages of the TIMSS 2007 Mathematics Assessment Devoted to Content Domains at Eighth Grade

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

The content domains define the specific mathematics subject matter covered by the TIMSS 2007 assessment at eighth grade. Each content domain has several topic areas; each one is presented as a list of objectives covered in the mathematics curriculum in the majority of participating countries. These grade specific objectives are written in terms of student understandings or abilities that items aligned with these objectives are designed to elicit. Sometimes the wording of objectives is similar or identical for fourth and eighth grades. In these instances, the progression in learning between the two grades is established by the difficulty of the items used. The following sections describe each of the mathematics content domains at eighth grade.

Number

The *number* content domain includes understanding of numbers, ways of representing numbers, relationships among numbers, and number systems.

At the eighth grade, students should have developed number sense and computational fluency, understand the meanings of operations and how they relate to one another, and be able to use numbers and operations to solve problems.

The number content domain consists of understandings and skills related to:

- Whole numbers
- Fractions and decimals
- Integers
- Ratio, proportion, and percent

The emphasis within computation is on fractions and decimals rather than on whole numbers. Within fractions and decimals, the emphasis is on representation and translation between forms, understanding what quantities the symbols represent, computation, and problem solving. By the eighth grade, students should be able to move flexibly among equivalent fractions, decimals, and percents using a range of strategies.

Eighth-grade students should have extended their mathematical understanding from whole numbers to integers, including order and magnitude as well as operations with integers. Students' should also be able to work with percents and proportions and use proportional reasoning to solve problems.

The problems students will be asked to solve include both the routine and the non-routine, those set in everyday contexts and those where mathematics itself is the context. Some problems involve computation with a range of measures and units of measurement.

Number: Whole Numbers

1. Demonstrate knowledge of place value and of the four operations.
2. Find and use multiples or factors of numbers, read scales, and identify prime numbers.

3. Use the principles of commutativity, associativity, and distributivity.
4. Evaluate powers of numbers, and square roots of perfect squares to 144.
5. Solve problems by computing, estimating, or approximating.

Number: Fractions and Decimals

1. Compare and order fractions and decimals.
2. Demonstrate knowledge of place value for decimals.
3. Represent decimals and fractions and operations with decimals and fractions using models (e.g., number lines); identify and use such representations.
4. Recognize and write equivalent fractions.
5. Convert between fractions and decimals.
6. Compute with fractions and decimals.
7. Solve problems by computing, estimating, and approximating.

Number: Integers

1. Represent, compare, order, and compute with integers.
2. Solve problems using integers.

Number: Ratio, Proportion, and Percent

1. Identify and find equivalent ratios; express ratios.
2. Divide a quantity in a given ratio.
3. Convert between percents and fractions or decimals.
4. Solve problems involving percents and proportions.

Algebra

While functional relationships and their uses for modeling and problem solving are of prime interest, it is also important to assess how well the supporting knowledge and skills have been learned. The *algebra* content domain includes recognizing and extending patterns, using algebraic symbols to represent mathematical situations, and developing fluency in producing equivalent expressions and solving linear equations.

The major topic areas in algebra are:

- Patterns
- Algebraic expressions
- Equations/formulas and functions

Algebraic concepts are relatively formalized by this grade, and students should have developed an understanding of linear relationships and the concept of variable. Students at this level are expected to use and simplify algebraic formulas, solve linear equations, inequalities, pairs of simultaneous equations involving two variables, and use a range of functions. They should be able to solve real-world problems using algebraic models and to explain relationships involving algebraic concepts.

Algebra: Patterns

1. Extend numeric, algebraic, and geometric patterns or sequences using numbers, words, symbols, or diagrams; find missing terms.
2. Generalize pattern relationships in a sequence, or between adjacent terms, or between the sequence number of the term and the term, using numbers, words, or algebraic expressions.

Algebra: Algebraic Expressions

1. Find sums, products, and powers of expressions containing variables.
2. Evaluate expressions for given numeric values of the variable(s).

3. Simplify or compare algebraic expressions to determine equivalence.
4. Model situations using expressions.

Algebra: Equations/Formulas and Functions

1. Evaluate equations/formulas given values of the variables.
2. Indicate whether a value (or values) satisfies a given equation/formula.
3. Solve simple linear equations and inequalities, and simultaneous (two variables) equations.
4. Recognize and write linear equations, inequalities, simultaneous equations, or functions that model given situations.
5. Recognize and generate equivalent representations of functions as ordered pairs, tables, graphs, or words.
6. Solve problems using equations/formulas and functions.

Geometry

Eighth-grade students should be able to analyze the properties and characteristics of a variety of two and three-dimensional geometric figures, including lengths of sides and sizes of angles, and to provide explanations based on geometric relationships. They should be able to apply the Pythagorean theorem to solve problems. The focus should be on using geometric properties and their relationships.

Alongside their appreciation of geometric properties and relationships, students also should be competent in geometric measurement, using measuring instruments accurately, estimating where appropriate, and selecting and using formulas for perimeters, areas, and volumes. The *geometry* content area also includes understanding coordinate representations and using spatial visualization skills to move between two- and three-dimensional shapes and their representations. Students should be able to use symmetry and apply transformation to analyze mathematical situations.

The three topic areas in geometry are:

- Geometric shapes
- Geometric measurement
- Location and movement

Spatial sense is integral to the study and assessment of geometry. The cognitive range extends from making drawings and constructions to mathematical reasoning about combinations of shapes and transformations. Students will be asked to describe, visualize, draw, and construct a variety of geometric figures, including angles, lines, triangles, quadrilaterals, and other polygons. Students should be able to combine, decompose, and analyze compound shapes. By this grade, they should be able to interpret or create top or side views of objects and use their understanding of similarity and congruence to solve problems.

Students should be able to use the Cartesian plane to locate points and lines. They should be able to recognize line symmetry and draw symmetrical figures. They should understand and be able to describe rotations, translations, and reflections in mathematical terms (e.g., center, direction, and angle).

As students progress through school, using proportional thinking in geometric contexts is important, as is making some initial links between geometry and algebra. Students should be able to solve problems using geometric models and explain relationships involving geometric concepts.

Geometry: Geometric Shapes

1. Classify angles as acute, right, straight, obtuse, and reflex (more than 180°); draw such angles.
2. Know and use the relationships for angles at a point, angles on a line, vertically opposite angles, angles associated with a transversal cutting parallel lines, angle bisection, and perpendicularity.
3. Recall and use geometric properties of geometric shapes: triangles, quadrilaterals, and other common polygons.

4. Construct or draw triangles and rectangles of given dimensions.
5. Identify congruent triangles, quadrilaterals and their corresponding measures.
6. Identify similar triangles and recall their properties.
7. Recognize relationships between three-dimensional shapes and their two-dimensional representations, (e.g., nets or two-dimensional views of three-dimensional objects).
8. Use Pythagorean theorem (not proof) to solve problems.
9. Apply geometric properties to solve problems.

Note: Eighth-grade geometric shapes items will involve circles, the following triangles – scalene, isosceles, equilateral, and right-angled; the following quadrilaterals – scalene, trapezoid, parallelogram, rectangle, rhombus, and square; as well as other polygons including pentagon, hexagon, octagon, and decagon.

Geometry: Geometric Measurement

1. Measure, draw, and estimate the size of given angles.
2. Measure, draw, and estimate the length of lines, perimeters, areas and volumes.
3. Select and use appropriate measurement formulas for perimeters, circumferences, areas of circles, surface areas, and volumes.
4. Find measures of irregular or compound areas (e.g., by covering with grids or dissecting and rearranging pieces).

Geometry: Location and Movement

1. Use ordered pairs, equations, intercepts, intersections, and gradient to locate points and lines in the Cartesian plane.
2. Recognize and use line and rotational symmetry for two-dimensional shapes, e.g. to draw symmetrical figures.
3. Recognize, or demonstrate by sketching, translation, reflection, and rotation.

Data and Chance

The *data and chance* content domain includes knowing how to organize data that have been collected by oneself or others and how to display data in graphs and charts that will be useful in answering questions that prompted the data collection. This content domain includes understanding issues related to misinterpretation of data.

The data and chance content domain consists of the following three major topic areas:

- Data organization and representation
- Data interpretation
- Chance

Students can engage in simple data-gathering plans or work with data that have been gathered by others or generated by simulations. They should understand what various numbers, symbols, and points mean in data displays. For example, they should recognize that some numbers represent the values of the data and others represent the frequency with which those values occur. Students should develop skill in representing their data, often using bar graphs, tables, or line graphs. They should be able to recognize and compare the relative merits of various types of displays.

Students should be able to describe and compare characteristics of data (shape, spread, and central tendency), and draw conclusions based on data displays. Students should be able to identify trends in data, make predictions based on data, and evaluate the reasonableness of interpretations.

Eighth-grade students' appreciation of chance (elementary probability) should include being able to designate the occurrence of familiar events as certain; as having greater, equal, or less likelihood; or as impossible, and should extend to using data from experiments or knowledge of equally likely outcomes to predict the chance of a given outcome.

Data and Chance: Data Organization and Representation

1. Read data from tables, pictographs, bar graphs, pie charts, and line graphs.
2. Organize and display data using tables, pictographs, bar graphs, pie charts, and line graphs.
3. Compare and match different representations of the same data.

Data and Chance: Data Interpretation

1. Identify, calculate and compare characteristics of data sets, including mean, median, range, and shape of distribution (in general terms).
2. Use and interpret data sets to answer questions and solve problems (e.g., draw conclusions, make predictions, and estimate values between and beyond given data points).
3. Recognize and describe approaches to organizing and displaying data that could lead to misinterpretation (e.g., inappropriate grouping and misleading or distorted scales).

Data and Chance: Chance

1. Judge the chance of an outcome as certain, more likely, equally likely, less likely, or impossible.
2. Use data from experiments to predict the chances of future outcomes.
3. Given a context, use the chances of a particular outcome to solve problems; determine the chances of possible outcomes (e.g., a particular face has a one-sixth chance of being on top after dropping a number cube).

Guidelines for Calculator Use

Although technology in the form of calculators and computers can help students learn mathematics, it should not be used to replace basic understanding and competencies. Like any teaching tool, calculators need to be used appropriately, and policies for their use differ across the TIMSS countries. Also, the availability of calculators varies widely. It would not be equitable to require calculator use when students in some countries may never have used them. Similarly, however, it is not equitable to deprive students of the use of a familiar tool.

After considerable debate on the issue, TIMSS 2003 introduced calculator use in the eighth-grade mathematics assessment. For newly developed items, calculators were not required, but were permitted if participating countries wanted to allow their students to use them. Based on a study conducted as part of TIMSS 2003 where the same items were given before the break when calculators were not permitted and in the session after the break when calculators were allowed, it was found that even without specifically planning nearly all the TIMSS mathematics items could be answered just as easily without the use of a calculator. That is, performance was not significantly different with or without a calculator for all except five items. Also, of the students who had calculators (63 percent), the vast majority (47 percent) reported that although they had calculators, they used them very little or not at all.

Based on the experience in TIMSS 2003, for TIMSS 2007 eighth-grade students will be permitted to use calculators for the entire assessment. As with previous TIMSS assessments, fourth-grade students will not be permitted to use calculators.

The aim of the TIMSS guidelines for calculator use is to give students the best opportunity to operate in settings that mirror their classroom experience. Thus, if students are used to having calculators for their classroom activities, then the country should encourage students to use them during the assessment. On the other hand, if students are not used to having calculators or are not permitted to use them in their daily mathematics lessons, then the country need not permit their use. In developing the new assessment materials, every effort will be made to ensure that the test questions do not advantage or disadvantage students either way – with or without calculators.

Mathematics Cognitive Domain – Fourth and Eighth Grades

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 2007, since 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, procedures, and concepts 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 multi-step problems.

These 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 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 5 shows the target percentages of testing time devoted to each cognitive domain for both the fourth- and eighth-grade assessments.

Exhibit 5: Target Percentages of the TIMSS 2007 Mathematics Assessment Devoted to Cognitive Domains at Fourth and Eighth Grades

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

Knowing

Facility in using mathematics, or reasoning about mathematical situations, depends on mathematical knowledge and familiarity with mathematical concepts. The more relevant knowledge a student is able to recall and the wider the range of concepts he or she has understood, the greater the potential for engaging a wide range of problem-solving situations and for developing mathematical understanding.

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 factual knowledge that provides the basic language of mathematics, and the essential mathematical facts and properties that form the foundation for mathematical thought.

Procedures form a bridge between more basic knowledge and the use of mathematics for solving routine 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.

Knowledge of concepts enables students to make connections between elements of knowledge that, at best, would otherwise be retained as isolated facts. It allows them to make extensions beyond their existing knowledge, judge the validity of mathematical statements and methods, and create mathematical representations.

This cognitive domain covers the following behaviors:

1. **Recall**	Recall definitions; terminology; number properties; geometric properties; and notation (e.g., $a \times b = ab$, $a + a + a = 3a$).

2.	**Recognize**	Recognize mathematical objects, shapes, numbers and expressions. Recognize mathematical entities that are mathematically equivalent (e.g., equivalent familiar fractions, decimals and percents; different orientations of simple geometric figures).
3.	**Compute**	Carry out algorithmic procedures for $+, -, \times, \div$, or a combination of these with whole numbers, fractions, decimals and integers. Approximate numbers to estimate computations. Carry out routine algebraic procedures.
4.	**Retrieve**	Retrieve information from graphs, tables or other sources; read simple scales.
5.	**Measure**	Use measuring instruments; use units of measurement appropriately; and estimate measures.
6.	**Classify/Order**	Classify/group objects, shapes, numbers and expressions according to common properties; make correct decisions about class membership; and order numbers and objects by attributes.

Applying

Problem solving is a central aim, and often means, of teaching school mathematics, and hence this and supporting skills (e.g., select, represent, model) feature prominently in the domain of *applying* knowledge and conceptual understanding. In items aligned with this domain, students need to apply mathematical knowledge of facts, skills, and procedures or understanding of mathematical concepts to create representations and solve problems. Representation of ideas forms the core of mathematical thinking and communication, and the ability to create equivalent representations are fundamental to success in the subject.

The problem settings are more routine than those aligned with the reasoning domain. The routine problems will typically have been standard in classroom exercises designed to provide practice in particular methods or techniques. Some of these problems will have been in words that set the problem situation in a quasi-real context. Though they range in difficulty, each of these types of "textbook" problems is expected to be sufficiently familiar to students that they will essentially involve selecting and applying learned procedures.

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. Therefore, problem solving is included not only in the *applying* domain, with emphasis on the more familiar and routine tasks but also in the *reasoning*, domain.

This cognitive domain covers the following behaviors:

1.	**Select**	Select an efficient/appropriate operation, method or strategy for solving problems where there is a known algorithm or method of solution.
2.	**Represent**	Display mathematical information and data in diagrams, tables, charts, or graphs, and generate equivalent representations for a given mathematical entity or relationship.
3.	**Model**	Generate an appropriate model, such as an equation or diagram for solving a routine problem.
4.	**Implement**	Follow and execute a set of mathematical instructions. Given specifications, draw figures and shapes.

5.	**Solve Routine Problems**	Solve routine problems (i.e., problems similar to those target students are likely to have encountered in class). For example, use geometric properties to solve problems. Compare and match different representations of data (eighth grade) and use data from charts, tables, graphs, and maps to solve routine problems.

Reasoning

Reasoning mathematically involves the capacity for logical, systematic thinking. It includes intuitive and inductive reasoning based on patterns and regularities that can be used to arrive at solutions to non-routine problems. Non-routine problems are problems that are very likely to be unfamiliar to students. They make cognitive demands over and above those needed for solution of routine problems, even when the knowledge and skills required for their solution have been learned. Non-routine problems may be purely mathematical or may have real-life settings. Both types of items involve transfer of knowledge and skills to new situations, and interactions among reasoning skills are usually a feature. Problems requiring reasoning may do so in different ways, because of the novelty of the context or the complexity of the situation or because any solution to the problem must involve several steps, perhaps drawing on knowledge and understanding from different areas of mathematics.

Even though of the many behaviors listed within the reasoning domain are those that may be drawn on in 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.

This cognitive domain covers the following behaviors:

1.	**Analyze**	Determine and describe or use relationships between variables or objects in mathematical situations; use proportional reasoning (fourth grade); decompose geometric figures to simplify solving a problem; draw the net of a given unfamiliar solid; visualize transformations of three-dimensional figures; compare and match different representations of the same data (fourth grade); and make valid inferences from given information.
2.	**Generalize**	Extend the domain to which the result of mathematical thinking and problem solving is applicable by restating results in more general and more widely applicable terms.
3.	**Synthesize/ Integrate**	Combine (various) mathematical procedures to establish results, and combine results to produce a further result. Make connections between different elements of knowledge and related representations, and make linkages between related mathematical ideas.
4.	**Justify**	Provide a justification for the truth or falsity of a statement by reference to mathematical results or properties.
5.	**Solve Non-routine Problems**	Solve problems set in mathematical or real life contexts where target students are unlikely to have encountered closely similar items, and apply mathematical procedures in unfamiliar or complex contexts. Use geometric properties to solve non-routine problems.

Chapter Two

TIMSS 2007 Science Framework

Overview

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

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

The content and cognitive domains are the foundation of the TIMSS 2007 fourth- and eighth-grade assessments. The content domains differ for the fourth and eighth grades, reflecting the nature and difficulty of the science widely taught at each grade. There is more emphasis at the fourth grade on life science than on its counterpart, biology, at the eighth grade. At the eighth grade, physics and chemistry are assessed as separate content domains, and receive more emphasis than at fourth grade, where they are assessed as one content domain, physical science. The cognitive framework, however, is the same for both grades, encompassing a range of cognitive processes involved in learning science concepts and knowledge and engaging in scientific inquiry right through the primary and middle school years. Exhibit 6 shows the target percentages of testing time devoted to each science content and cognitive domain for the fourth- and eighth-grade assessments.

Exhibit 6: Target Percentages of the TIMSS 2007 Science Assessment Devoted to Content and Cognitive Domains at Fourth and Eighth Grades

Fourth-Grade Content Domains	Percentages
Life Science	45%
Physical Science	35%
Earth Science	20%
Eighth-Grade Content Domains	**Percentages**
Biology	35%
Chemistry	20%
Physics	25%
Earth Science	20%

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

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

Science Content Domains – Fourth Grade

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

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

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

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

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

Life Science

Life science includes understandings of the characteristics and life processes of living things, the relationships between them, and their interaction with the environment. The topic areas for life science are as follows:

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

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

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

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

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

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

Life Science: Characteristics and Life Processes of Living Things

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

Life Science: Life Cycles, Reproduction, and Heredity

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

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Life Science: Interactions with the Environment

1. Associate physical features of plants and animals with the environments in which they live; identify or provide examples of certain physical or behavioral characteristics of plants and animals that make them better suited for survival in particular environments and explain why (e.g., color change, fur thickness, hibernation, migration).

2. Describe bodily actions in response to outside conditions (e.g., heat, cold, danger) and activities (e.g., exercise).

Life Science: Ecosystems

1. Understand that plants need the sun to make their own food, while animals consume plants or other animals as food; recognize that all plants and animals need food to provide energy for activity and raw material for growth and repair.

2. Explain relationships in a given community (e.g., forest, tidepool) based on simple food chains, using common plants and animals and predator-prey relationships.

3. Present ways in which human behavior can have a positive or a negative effect on environments; provide general descriptions and examples of the effects of pollution on humans, plants, animals, and their environments, and ways of preventing or reducing pollution.

Life Science: Human Health

1. Recognize ways that common communicable diseases (e.g., colds, influenza) are transmitted; identify signs of health or illness and some methods of preventing and treating illness.

2. Describe ways of maintaining good health, including the need for a balanced diet, identification of common food sources (e.g., fruits and vegetables, grains), and the effect of personal habits on health (e.g., regular exercise, nutritious diet).

Physical Science

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

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

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

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

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

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

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

Physical Science: Classification and Properties of Matter

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

Physical Science: Physical States and Changes in Matter

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

Physical Science: Energy Sources, Heat, and Temperature

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

Physical Science: Light and Sound

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

Physical Science: Electricity and Magnetism

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

Physical Science: Forces and Motion

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

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

Earth Science

Earth science is concerned with the study of Earth and its place in the solar system. While there is no single picture of what constitutes an Earth science curriculum that applies to all countries, the TIMSS 2007 framework identifies the following topic areas that are universally considered to be important for students at the fourth grade to understand about the planet on which they live and its place in the solar system:

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

Fourth-grade students are expected to have some general knowledge about the structure and physical characteristics of Earth. They should know that solid Earth is composed of rocks, sand, and soil, and that most of Earth's surface is covered by water. Students also should have some understanding of the uses and conservation of Earth's resources such as soil and fresh water. At this level, assessment of students' understandings of the atmosphere is limited to evidence for the presence of water and the importance of air for the survival of living things. They are also expected to know common features of Earth's landscape.

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

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

SCIENCE FRAMEWORK

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

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

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

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

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

Earth in the Solar System

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

Science Content Domains – Eighth Grade

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

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

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

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

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

Biology

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

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

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

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

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

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

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

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

Biology: Characteristics, Classification, and Life Processes of Organisms

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

Biology: Cells and Their Functions

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

Biology: Life Cycles, Reproduction, and Heredity

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

Biology: Diversity, Adaptation, and Natural Selection

1. Relate the survival or extinction of different species to variation in physical/behavioral characteristics in a population and reproductive success in changing environments.

2. Recognize the relative length of time major groups of organisms have existed on Earth (e.g., humans, reptiles, fish, plants); describe how similarities and differences among living species and fossils provide evidence of the changes that occur in living things over time.

Biology: Ecosystems

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

5. Describe the impact of natural hazards (e.g., earthquakes, landslides, wildfires, volcanic eruptions, floods, storms) on humans, wild life, and the environment.

Biology: Human Health

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

Chemistry

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

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

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

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

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

Chemistry: Classification and Composition of Matter

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

Chemistry: Properties of Matter

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

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

Chemistry: Chemical Change

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

Physics

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

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

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

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

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

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

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

Physics: Physical States and Changes in Matter

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

Physics: Energy Transformations, Heat, and Temperature

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

Physics: Light

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

Physics: Sound

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

Physics: Electricity and Magnetism

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

Physics: Forces and Motion

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

Earth Science

Earth science is concerned with the study of Earth and its place in the solar system and the universe. Topics covered in the teaching and learning of Earth science draw on the fields of geology, astronomy, meteorology, hydrology, and oceanography, and are related to concepts in biology, physics, and chemistry. Although separate courses in Earth science covering all of these topics are not taught in all countries, it is expected that understandings related to Earth science topic areas will have been included in a science curriculum covering the physical and life sciences or in separate courses such as geography and geology. While there is no single picture of what constitutes an Earth science curriculum that applies to all countries, the TIMSS 2007 framework identifies the following topic areas that are universally considered to be important for students at the eighth grade to understand about the planet on which they live and its place in the universe:

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

Eighth-grade students are expected to have some general knowledge about the structure and physical features of Earth. They are expected to demonstrate knowledge of the structure and physical characteristics of Earth's crust, mantle, and core, and to describe the distribution of water on Earth, including its physical state, composition, and movement. Students are expected to be familiar with the relative abundance of the main components of air, and with changes in atmospheric conditions in relation to altitude.

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

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

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

Earth Science: Earth's Structure and Physical Features

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

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

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

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

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

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

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

Earth Science: Earth in the Solar System and the Universe

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

Science Cognitive Domains – Fourth and Eighth Grades

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

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

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

These three cognitive domains are used at both grades, however the percentages vary between fourth and eighth grade in accordance with the increased cognitive ability, maturity, instruction, experience, and breadth and depth of understanding of students at the higher grade level (see Exhibit 9). Thus the percentage of items that involve knowing is higher at the fourth grade while the percentage of items that ask students to engage in reasoning is higher at the eighth grade. For fourth and eighth grades, each content domain will include items developed to address each of the three cognitive domains. For example, the life science content domain will include knowing, applying, and reasoning items, as will the other content domains.

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

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

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

Knowing

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

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

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

Applying

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

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

Reasoning

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

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

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

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

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

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

Scientific Inquiry

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

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

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

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

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

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

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

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

Chapter Three

TIMSS 2007 Contextual Framework

Overview

Learning takes place within a context, and not in isolation. There are numerous contextual factors that effect students' learning. For example, type of school, school resources, instructional approaches, teacher characteristics, student attitudes, and home support for learning contribute heavily to student learning and achievement. For a fuller appreciation of what the TIMSS achievement results mean and how they may be used to improve students learning in mathematics and science, it is important to understand the contexts in which students learn. TIMSS in every cycle collects a range of information about these contexts for learning, together with assessing students' performance in mathematics and science. The TIMSS 2007 Contextual Framework encompasses five broad areas on which information is collected:

- Curriculum
- Schools
- Teachers and Their Preparation
- Classroom Activities and Characteristics
- Students

In particular, TIMSS examines the curricular goals of the education system and how the system is organized to attain those goals; the educational resources and facilities provided; the teaching force and how it is educated, equipped, and supported; classroom activities and characteristics; home support and involvement; and the knowledge and attitudes that students and teachers themselves bring to the educational enterprise. Just as the mathematics and science frameworks describe what should be assessed in those areas, the contextual framework identifies the major characteristics of the educational and social contexts that will be studied with a view to improving student learning.

The Curriculum

Building on IEA's experience and past TIMSS studies, the TIMSS 2007 contextual framework addresses five broad aspects of the intended curriculum in mathematics and science, from its formulation to its implementation.

Formulating the Curriculum

Curriculum development involves consideration of the society which the education system serves. The curriculum reflects the needs and aspirations of the students, the nature and function of learning, and the formulation of statements on what learning is important. In understanding the intended curriculum, it is important to know who makes the curricular decisions, what types of decisions are made, and how decisions are communicated to the education community.

Scope and Content of the Curriculum

Curricular documents define and communicate expectations for students in terms of the knowledge, skills, and attitudes to be acquired or developed through their formal education. The nature and extent of the mathematics and science goals to be attained in school are important to policy makers and curriculum specialists in all countries. Also important is how these goals are kept current in the face of scientific and technological advances, and how the demands and expectations of society and the workplace change. As a related issue, curricular documents can include policies about using technology (e.g., calculators, computers, and the internet) in the schools and classrooms.

Although mastery of the subject is a major focus of mathematics and science curricula in most countries, countries differ considerably in how the curriculum specifies that mastery should be achieved. For example, acquiring basic skills, understanding mathematical concepts and principles, applying mathematics to "real-life" situations, communicating mathematically, reasoning mathematically and problem solving in novel situations are approaches to teaching mathematics that have been advocated in recent years and are used to varying degrees in different countries.[1] In science, focus on the acquisition of basic science facts, the understanding and application of science concepts, emphasis on formulating a hypothesis, designing and conducting investigations to test a hypothesis, and communicating scientific explanations are teaching strategies that are emphasized in some countries more than in others.[2]

Organization of the Curriculum

The way the education system – national, regional, and local – is organized has a significant impact on students' opportunities to learn mathematics and science. At the school level, the relative emphasis on and amount of time specified for mathematics, science, and other subjects up through various grade levels can greatly affect such opportunities. Practices such as tracking, streaming, and setting can expose students to different curricula. In science, teaching the major components of science as separate subjects can result in different experiences for students compared with the science-as-single-subject approach.

Monitoring and Evaluating the Implemented Curriculum

Many countries have systems in place for monitoring and evaluating the implementation of the curriculum and for assessing the status of their education systems. Commonly used methods include standardized tests, school inspection, and audits. Policy makers may use influences external to the school, for example national or regional standardized tests, to prescribe the implementation of the curriculum. Policy makers also may work collaboratively with the school community (or selected subpopulations) to develop, implement, and evaluate the curriculum.

Curricular Materials and Support

Apart from the use of standardized tests, inspections, and audits, countries can employ a range of other strategies to facilitate the implementation of the intended curriculum. These include training teachers in

1 Mullis, I.V.S., Martin, M.O., Gonzalez, E.J., and Chrostowski, S.J., (2004). *TIMSS 2003 international mathematics report: Findings from IEA's trends in international mathematics and science study at the fourth and eighth grades*, Chestnut Hill, MA: Boston College.

2 Martin, M.O., Mullis, I.V.S., Gonzalez, E.J., and Chrostowski, S.J., (2004). *TIMSS 2003 international science report: Findings from IEA's trends in international mathematics and science study at the fourth and eighth grades*, Chestnut Hill, MA: Boston College.

the content and pedagogic approaches specified in the curriculum. Such training may be an integral part of the teacher education curriculum, or it may be included in professional development programs. The implementation of the curriculum can be further supported through the development and use of teaching materials, including textbooks, instructional guides, and ministerial notes, that are specifically tailored to the curriculum.

The Schools

In the TIMSS 2007 contextual model, the school is the institution through which the goals of the curriculum are implemented. Accepting that a high quality 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, TIMSS focuses on a set of indicators of school quality that research has shown to characterize such schools.

School Demographics

School size, its location, and characteristics of its student body impact how the school system works. There is no clear agreement among researchers and educators about what constitutes a "small" school or a "large" school. Schools must be large enough so that the necessary investment in libraries, laboratories, gymnasia, and the like is economically sound but not so large as to be organizationally cumbersome to run.[3] Research has shown that students in small schools are involved in a greater variety of activities and derive more satisfaction from their participation than students in large schools. Interpersonal relations between and among students, teachers, and administrators are more positive in small schools than in large ones.[4]

It is also important to know about the composition of a school's student body. Frequent turnovers of the student body can affect continuity of instruction and can disrupt student learning. Schools with a large number of students coming from economically disadvantaged families generally have lower student achievement because of less

3 Martin, M.O., Mullis, I.V.S., Gregory, K.D., Hoyle, C., and Shen, C. (2000). *Effective schools in science and mathematics*, Chestnut Hill, MA: Boston College.

4 Bates, J. T. (1993). *Portrait of a successful rural alternative school*. *Rural Educator*, 14(3), 20-24.

supportive home environments, difficulty in recruiting and retaining good teachers in the school, fewer resources and more student behavior problems.

School Organization

Whether as part of a larger national, regional, or local education system or because of decisions made at the school level, science and mathematics instruction is carried out within certain organizational constraints. For example, the time in terms of days per year and minutes per day allotted for schooling, and in particular for mathematics and science instruction, can influence achievement. It is also important to know about different types of schools, since some schools may specialize. For example, in countries with tracking, the school may be designated to emphasize either an academic or a vocational curriculum.

School Goals

Research on effective schools suggests that successful schools identify and communicate ambitious but reasonable goals and work toward implementing them. Commonly articulated school goals include basic literacy, academic excellence, personal growth, human relation skills, good work habits, and self-discipline.[5]

Roles of the School Principal

Research shows that achievement improves in schools where principals are effective instructional leaders.[6] The school principal typically fulfills multiple leadership roles. These include ensuring that the school, its operation, and its resources are managed optimally. The principal may guide the school in setting directions, seeking future opportunities, and building and sustaining a learning environment. He or she can facilitate the development, articulation, implementation, stewardship, and evaluation of a model of learning that is shared and supported by the school community. The principal may actively advocate, nurture, and sustain a positive school culture and an education program conducive

5 Henke, R.R., Choy, S.P., Geis, S. and Broughmann, S.P. (1996). *Schools and staffing in the united states: A statistical profile, 1993-94(NCES 96-124)*. US Department of Education, National Center for Education Statistics. Washington, DC: US Government Printing Office.

6 DuFour, R. (1999). *Help wanted: Principals who can lead learning communities*. NASSP Bulletin, 12-17.

to student learning and teachers' professional growth. The primary roles that the principal fulfills provide a useful indication of the administrative and educational structure of the school.

Resources to Support Mathematics and Science Learning

Curriculum implementation can be facilitated by allocating the facilities, materials, and equipment necessary to achieve the specified learning goals. Results from TIMSS indicate that students in schools that are well resourced generally have higher achievement than those in schools where shortages in resources affect capacity to implement the curriculum. Two types of resources affect implementation of the curriculum. General resources include teaching materials, budget for supplies, school buildings and supplies, heating/cooling and lighting systems, and classroom space. Subject-specific resources for mathematics and science may include computers, computer software, calculators, laboratory equipment and materials, library materials, and audio-visual resources.

Technology, Support, and Equipment

While computers are undoubtedly changing the educational landscape, schools operate with finite resources, and the allocation of money, time, and space for technology may divert scarce resources from other priorities, such as increasing teacher salaries, teachers' professional development, lowering student-teacher ratios, and the provision of teaching resources including laboratory equipment and space. Further, the sustainability of school computer systems, and the continuity of support staffing may be as important as the acquisition of the computers.

The effective and efficient use of computers requires suitable training of teachers, students, and school staff. Use of computers can also be enhanced by providing access to the internet for educational purposes. Factors limiting computer use include the lack of appropriate software and hardware, software not congruent with the curriculum, lack of teacher training and support, and lack of funding for computer repair and maintenance.

School Social Climate

A school's social climate comprises the values, cultures, safety practices, and organizational structures that cause it to function and react in particular ways. Respect for individual students and teachers, a safe and orderly environment, constructive interactions among administrators, teachers, parents, and students all contribute to a positive school climate. A supportive school climate helps to build better morale among teachers and students and that leads to higher student achievement. Although a safe and orderly school environment does not in and of itself guarantee high levels of student achievement, student learning can be more difficult in schools where student discipline is a problem, where students are regularly absent or late to class, or where they fear injury or loss of personal property. For validation purposes, it is important to collect information about school climate as perceived by teachers, students, and principals. School-wide programs that provide for the basic needs of students and their families (e.g., Lunches for students, after-school child care, or adult literacy programs) may also be important.

Parental Involvement

A significant body of research indicates that when parents participate in their children's education, the result is an increase in student achievement and an improvement of students' attitudes. Increased attendance, fewer discipline problems, and higher aspirations also have been correlated with an increase in parent involvement.[7] Effective schools reach out to their parent communities and provide structure for the parents to be involved in their children's school. Parental involvement can be in the areas of checking homework, volunteering for field trips, and fund raising. Parents also can get involved in the decision-making or administrative processes of the school (e.g., selecting school personnel, reviewing or making decision for school finances, etc.).

Teacher Recruitment

The growth of technology in recent years has meant that education systems must compete with industry for the best mathematics and

7 Henderson, A. T., & Berla, N. (1994). *A new generation of evidence: The family is critical to student achievement*. St. Louis, MO: Danforth Foundation and Flint, MI: Mott (C. S.) Foundation.

science candidates. The rapid advancement of mathematics and science necessitates that prospective teachers be capable of keeping pace with these fast-evolving fields. This calls for the attraction of top-level applicants who are capable of adjusting their teaching to the evolving demands of modern education. Employment contracts, incentives such as free college education, attractive pay, housing facility, and giving bonuses to deserving teachers are some of the methods used to recruit suitable candidates.

Teacher Evaluation

The general purpose of teacher evaluation is to safeguard and improve the quality of instruction received by students. There are numerous ways to evaluate teachers. One way is observation of their teaching by the principal, inspectors or senior member of the staff. Some of other methods that can be used for evaluating teachers quality are student achievement and teacher peer review. Schools can use anyone of them or combination of these ways. However, to improve and enhance classroom instructional practices schools must also provide a process that allows and encourages supervisors and teachers to work together.

Teachers and Their Preparation

Teachers are the primary agents of curriculum implementation. Regardless of how closely prescribed the curriculum, or how explicit the textbook, it is the actions of the teacher in the classroom that most affect student learning. What teachers know and are able to do is of critical importance. A recent review suggests that to ensure excellence, teachers should have high academic skills, teach in the field in which they received their training, have more than a few years of experience, and participate in high-quality induction and professional development programs.[8]

Academic Preparation and Certification

Aware of the key role played by the teacher in implementing the curriculum, many countries are focusing on improving education for

8 Mayer, D.P., Mullens, J.E., and Moore, M.T. (2000). *Monitoring school quality: An indicators report, NCES 2001-030*, Washington, DC: National Center for Education Statistics.

aspiring teachers, particularly the mathematics and science prerequisites necessary for effective teaching in these subject areas.

The authority or organization responsible for granting certification for teachers and the methods of certification to teach vary widely across countries. The methods might include the completing of specified courses, passing exams, supervised practical experience, obtaining a university degree, serving a probation period, and completion of an induction program. In some countries there may be alternative methods of being certified, especially in subject areas with a shortage of teachers.

The relative emphasis on content knowledge and pedagogic approach of trainee teachers, and how teacher education programs keep abreast of the changes brought about by rapid advances in science and technology, are important features of teacher preparation programs. They employ different teaching methods to prepare teachers to teach their subject matter and to enable them to become broadly educated, reflective, professional educators. Developing a lifelong positive attitude toward learning also may be an important facet of teacher education. Collaboration between universities and schools and the use of teacher competency standards may further contribute to good academic preparation. In many countries future teachers are prepared to teach the intended curriculum as part of both pre- and in-service training.

Teacher Assignment

TIMSS has shown that there is considerable variation across countries in the level of education teachers complete as well as in the percentage of students taught mathematics or science by teachers with a major in the subject. While there can be both problems and benefits associated with teachers teaching "out of field," of interest is how such teachers acquire the subject-specific knowledge they need in order to teach effectively.

Teacher Induction

The transition from university to a school teaching position can be difficult. Consequently, in many countries a large percentage of new teachers leave the profession after only a few years of teaching.[9] The extent to which schools take an active role in the acculturation and transition of the new teacher may be important. Mentoring, the modeling of good teacher practice by peers, and induction programs designed by experienced teachers within the school may be important to aid the beginning teacher.

Professional Development

The professional development of teachers is of central importance to any attempts to change or reform an education system. Unless teachers participate in ongoing professional development activities, they risk being uninformed about key developments in education and in their subject areas that have occurred since they received their initial training.

Focus on academic subject matter, opportunities for active learning (observing and being observed teaching, planning for classroom implementation, reviewing student work, giving a lecture or presentation, writing a lesson plan), and coherence with other learning activities going on in the daily life of the school are important features of successful teacher professional development activities.[10] There is special concern that without access to high-quality professional development, teachers will be unable to benefit from the advances made in information technology.

Teacher Characteristics

Some literature examines the influence of teacher gender, age, and experience on student achievement. Studies have suggested that students learn more when taught by experienced teachers than they do when taught by teachers with just a few years' experience. However, the relationship between experience and achievement may be affected by many factors. For example, assignment policies within schools may

9 Moskowitz, J. and Stephens, M., eds. (1997). *From students of teaching to teachers of students: Teacher induction around the pacific rim*, Washington, DC: U.S. Department of Education.

10 Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal*, 38(4), 915-945.

result in the more highly skilled teachers getting specific classes, or older teachers getting higher-tracked classes. The need for longserving teachers to engage in professional development, and the extent to which they do so, can also impact their effectiveness.

Classroom Activities and Characteristics

Although the school provides the general context for learning, it is in the classroom setting and through the guidance of the teacher that most teaching and learning take place. The classroom setting here is taken to include work assigned in the classroom but completed elsewhere, such as homework, library assignments, or field work. Aspects of the implemented curriculum that are most readily studied in the classroom include the curriculum topics that are actually addressed, the pedagogic approaches used, the materials and equipment available, and the conditions under which learning takes place, including the size and composition of the class and the amount of classroom time devoted to mathematics and science education.

Curriculum Topics Taught

A major focus of the implemented curriculum is the extent to which the mathematics and science topics in the TIMSS frameworks are covered in the classroom. TIMSS addresses this question by asking the mathematics and science teachers of the students assessed to indicate whether each of the topics tested has been covered in class, either in the current or previous years, and the percentage of time in class devoted to each of the TIMSS mathematics and science content domains. TIMSS characterizes the coverage and level of rigor of the mathematics and science courses taught in participating countries by describing the main focus of the work in the classes being tested.

Class Size

Class size can serve as an economic indicator, with smaller classes signifying greater wealth. However, smaller class sizes may be the result of government policies that cap class size. Further, class size may reflect selective resource allocation to, for example, special needs or practical classes. Whatever the reason for the class size, there is little doubt that it affects how teachers implement the curriculum.

Instructional Time

The amount of classroom instructional time devoted to mathematics and science is an important aspect of curricular implementation. TIMSS has shown that the efficient use of that time and the disruptive effects of outside interruptions are aspects related to effective teaching.

Instructional Activities

Teachers employ a variety of strategies to encourage students to learn. Some of these methods are more effective than others in contributing to student achievement. Information on how teachers allot their time to such activities as lecture-style presentation, teacher-guided student practice, re-teaching and clarifying content and procedures, small group work, and independent practice, for example, provides useful evidence about the predominant pedagogic approaches in the classroom. Student reports of how much time they spend being shown how to do mathematics and science, working from worksheets or textbooks, working on projects on their own or in small groups, or discussing homework also provide important information about classroom activities. For example, studies have shown students who conduct hands-on learning activities outperform their peers as do students who have the benefit of individualized instruction.[11]

Assessment and Homework

TIMSS results show that teachers devote a fair amount of time to student assessment, whether as a means of gauging what students have learned to guide future learning, or for providing feedback to students, teachers, and parents. The frequency and format of assessment are important indicators of teaching and school pedagogy.

Homework is a way to extend instruction and assess student progress. It serves to increase the time devoted to a subject. The reasons

11 Wenglinsky, H. (2000). *How teaching matters: Bringing the classroom back into discussions of teacher quality*. Educational Testing Service, Princeton, NJ. Policy Information Center.

for assigning homework as well as the amount and types assigned are important pedagogic considerations. It can be used to reinforce and/or extend the concepts developed in a lesson.

Computer and Internet Use

The computer is rapidly transforming education as students prepare to enter the technological workforce. Computers and the internet provide students new ways to explore concepts at a depth that has not been possible in the past. These technological tools can trigger a new enthusiasm and motivation for learning, enable students to learn at their own pace, and provide students with access to vast information sources.

There is evidence to show that multiple layers of access to the internet, for example at schools, in libraries, and at home, is important. For countries in which students do have ready access to the internet, it is important that they be taught how to use the information, and how to evaluate its truth or worth.

Besides giving students access to the internet, computers can serve a number of other educational purposes. While initially limited to learning drills and practice, they are now used in a variety of ways including tutorials, simulations, games, and applications. New software enables students to pose their own problems and explore and discover mathematics and scientific properties on their own. Computer software for modeling and visualization of ideas can open a whole new world to students and help them connect these ideas to their language and symbol systems.

Calculator Use

Calculator use varies widely among, and even within, countries, but generally is increasing steadily as cost becomes less of an impediment and mathematics curricula evolve to take calculators into account. Many countries have policies regulating the access to and use of calculators, especially at the earlier grade levels. What those policies are and how they change over the grades can be important in understanding the curriculum.

Calculators can be used in exploring number recognition, counting, and the concepts of larger and smaller. They can allow students to solve numerical problems faster by eliminating tedious computation and thus become more involved in the learning process. How best to make use of calculators, and what role they should have, continue to be questions of importance to mathematics curriculum specialists and teachers.

Emphasis on Investigations

The emphasis on conducting projects and investigations varies widely across countries. An exploration of the frequency and the nature of a task can illuminate the learning at issue. In science, practical investigations often are an integral part of the learning process. The extent to which these activities are demonstrated by the teacher and conducted by the students also shows variation across countries.

The Students

Home Background

Students come to school from different backgrounds and with different experiences. The number of books in the home, availability of a study desk, the presence of a computer, the educational level of the parents, and the extent to which students speak the language of instruction have been shown to be important home background variables, indicative of the family's socio-economic status, that are related to academic achievement. Such factors are also indicative of the home support for learning and can influence students' overall educational aspirations. The extent to which employment, sports and recreational pastimes, and other activities occupy the student's time may also affect learning.

Attitudes

Creating a positive attitude in students toward mathematics and science is an important goal of the curriculum in many countries. Students' motivation to learn can be affected by whether they find the subject enjoyable, place value on the subject, and think it is important in the present and for future career aspirations. In addition, students' motivation can be affected by their self confidence in learning the subject.

Chapter Four

TIMSS 2007 Assessment Design

Overview

The TIMSS 2007 international assessment of student achievement comprises written tests in mathematics and science together with a set of questionnaires that gather information on the educational and social contexts for achievement. Central to the 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' improvement or decline 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.

To maximize the information provided to educators and policy makers, TIMSS reports student performance in the major content domains of the subjects (i.e., number, algebra, geometry, and data and chance in mathematics at the eighth grade and biology, chemistry, physics, and earth science in eighth-grade science) as well as performance in mathematics and science overall. In addition, TIMSS in 2007 will for the first time report student achievement by cognitive domain – i.e., knowing, applying, and reasoning. These ambitious coverage and reporting goals make for enormously valuable information for policy decisions, teacher education, and instructional practices, but pose significant challenges for data collection, analysis, and reporting.

A major consequence of TIMSS' ambitious assessment goals is that there are many more questions on the assessment than can be answered by a student in the amount of testing time available. Accordingly, TIMSS 2007 uses a matrix-sampling approach that involves packaging the entire assessment pool of mathematics and science questions into a set of 14 student achievement booklets, with each student completing just one booklet. Each question, or item, appears in two booklets, providing a mechanism for linking together the student responses from the various booklets. Booklets are distributed among students in participating classrooms so that the groups of students completing each booklet are approximately equivalent in terms of student ability. Using Item-Response Theory (IRT) scaling techniques, a comprehensive picture of the achievement of the entire student population is assembled from the combined responses of individual students to the booklets they are assigned. This approach reduces to manageable proportions what otherwise would be an impossible student burden, albeit at the cost of greater complexity in booklet assembly, data collection, and data analysis.

TIMSS 2007 Item Blocks

To facilitate the process of creating the student achievement booklets, TIMSS groups the assessment items into a series of item blocks, with approximately 10-15 items in each block. As in the TIMSS 2003 assessment, TIMSS 2007 has 28 blocks in total, 14 containing mathematics items and 14 containing science items. Student booklets were assembled from various combinations of these item blocks.

Following the 2003 assessment, half of the mathematics blocks and half of the science blocks were secured for use in measuring trends in 2007. The remaining blocks were released into the public domain for use in publications, research, and teaching, to be replaced by newly-developed items in the TIMSS 2007 assessment. Accordingly, the 28 blocks in the TIMSS 2007 assessment comprise 14 blocks of trend items (seven mathematics and seven science) and 14 blocks of new items developed for 2007. As shown in Exhibit 10, the TIMSS 2007 mathematics blocks are labeled M01 through M14 and the science blocks S01 through S14. Blocks with labels ending in odd numbers (01, 03, 05, etc.) contain the trend items from the 2003 assessment, and those ending in even numbers the new items developed for use for the first time in TIMSS 2007.

Exhibit 10: TIMSS 2007 Student Booklet Design – Fourth and Eighth Grades

Mathematics Blocks	Source of Items	Science Blocks	Source of Items
M01	Block M05 from TIMSS 2003	S01	Block S14 from TIMSS 2003
M02	New items for TIMSS 2007	S02	New items for TIMSS 2007
M03	Block M06 from TIMSS 2003	S03	Block S05 from TIMSS 2003
M04	New items for TIMSS 2007	S04	New items for TIMSS 2007
M05	Block M07 from TIMSS 2003	S05	Block S06 from TIMSS 2003
M06	New items for TIMSS 2007	S06	New items for TIMSS 2007
M07	Block M08 from TIMSS 2003	S07	Block S07 from TIMSS 2003
M08	New items for TIMSS 2007	S08	New items for TIMSS 2007
M09	Block M11 from TIMSS 2003	S09	Block S08 from TIMSS 2003
M10	New items for TIMSS 2007	S10	New items for TIMSS 2007
M11	Block M12 from TIMSS 2003	S11	Block S11 from TIMSS 2003
M12	New items for TIMSS 2007	S12	New items for TIMSS 2007
M13	Block M14 from TIMSS 2003	S13	Block S12 from TIMSS 2003
M14	New items for TIMSS 2007	S14	New items for TIMSS 2007

Although the general arrangement of items into blocks follows the 2003 approach, based on experience from that assessment the estimated amount of time needed by students to complete a block was increased – from 15 to 22.5 minutes at eighth grade and from 12 to 18 at fourth grade. Consequently, the 28 blocks of eighth-grade items contain an estimated 10½ hours of testing time and the fourth-grade blocks, almost 8½ hours. From past experience with TIMSS, 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 had to fit into 90 minutes for eighth grade and 72 minutes for fourth grade. An additional 30 minutes for a student questionnaire also was planned at each grade level.

TIMSS 2007 Block Design for Student Achievement Booklets

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 trends in the mathematics and science content areas could be measured reliably. To enable linking among booklets while keeping the number of booklets to a minimum, each block appears in two booklets.

In the TIMSS 2007 design, the 28 assessment blocks are distributed across 14 student achievement booklets (see Exhibit 11). The same booklet design is used at both fourth and eighth grade, although the eighth-grade blocks contains 22.5 minutes of assessment items and the fourth grade blocks 18 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 mathematics blocks come first, followed by the science blocks, and in the other half the order is reversed. Additionally, two of the blocks in each booklet contain trend items from 2003 and two contain items newly developed for TIMSS 2007. For example, as may be seen from Exhibit 11, 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 2003, while those in M02 and S02 are items new for TIMSS 2007. 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.

Exhibit 11: TIMSS 2007 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

As summarized in Exhibit 12, each student completes one student achievement booklet in two parts, followed by a student questionnaire. The individual student response burden for the assessment is similar to TIMSS in 2003, i.e., 72 minutes for the assessment and 30 minutes for the questionnaire at fourth grade, and 90 minutes and 30 minutes, respectively, at eighth grade.

Exhibit 12: TIMSS 2007 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

Countries participating in TIMSS aim for a sample of at least 4,500 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.

Question Types and Scoring Procedures

Students' knowledge and understanding of mathematics and science are assessed through a range of questions in each subject. Two question formats are used in the TIMSS assessment – multiple-choice and constructed-response. At least half of the total number of points represented by all the questions will come from multiple-choice questions. Each multiple-choice question is worth one score point.

Constructed-response questions generally are worth one or two score points, depending on the nature of the task and the skills required to complete it. However, building on the TIMSS 2003 special initiative to develop problem solving and inquiry tasks (known as PSIs) funded by the US National Science Foundation, TIMSS 2007 will have extended reasoning tasks or item sets of related problems. In particular, these reasoning tasks address the thinking skills described in the reasoning cognitive domain in the mathematics and science frameworks, respectively. For the reasoning tasks or item sets, the number of possible points, typically three to six points, depends on the requirements for students to successfully complete the task. In developing assessment questions, the choice of item format depends on the mathematics or science being assessed, and the format that best enables students to demonstrate their proficiency.

Multiple-Choice Questions. Multiple-choice questions provide students with four response options, of which only one is correct. These questions can be used to assess any of the behaviors in the cognitive domains. However, because they do not allow for students' explanations or supporting statements, multiple-choice questions may be less suitable for assessing students' ability to make more complex interpretations or evaluations.

In assessing fourth- and eighth-grade students, it is important that linguistic features of the questions be developmentally appropriate. Therefore, the questions are written clearly and concisely. The response options also are written succinctly in order to minimize the reading load of the question. The options that are incorrect are written to be plausible, but not deceptive. For students who may be unfamiliar with this test question format, the instructions given at the beginning of the test include a sample multiple- choice item that illustrates how to select and mark an answer.

Constructed-Response Questions. For this type of test item students are required to construct a written response, rather than select a response from a set of options. Constructed-response questions are particularly well-suited for assessing aspects of knowledge and skills that require students to explain phenomena or interpret data based on their background knowledge and experience.

The scoring guide for each constructed-response question describes the essential features of appropriate and complete responses. The guides focus on evidence of the type of behavior the question assesses. They describe evidence of partially correct and completely correct responses. In addition, sample student responses at each level of understanding provide important guidance to those who will be rating the students' responses. In scoring students' responses to constructed-response questions, the focus is solely on students' achievement with respect to the topic being assessed, not on their ability to write well. However, students need to communicate in a manner that will be clear to those scoring their responses.

In addition, scoring guides are designed to enable, for each item, identification of the various successful, partially successful, and unsuccessful approaches. Diagnosis of common learning difficulties in mathematics and science as evidenced by misconceptions and errors is an important aim of the study.

Since constructed-response questions constitute an important part of the assessment and are an integral part of the measurement of trends, it is very important for scoring guides to be implemented consistently in all countries and in each data collection year. To ensure consistent application of the scoring guides for trend items in the 2007 assessment, IEA has archived samples of student responses to previous assessments from each country; these are used to train scorers in 2007 and to monitor consistent application.

Score Points. In developing the assessment, the aim is to create blocks of items that each provide, on average, about 15 score points at eighth grade and about 12 score points at fourth grade. Item blocks contain a variety of item types, including multiple-choice items (1 point each) and constructed-response items (1,2, or more points) that allow for partial as well as full credit. The exact number of score points and the exact distribution of question types per block varies somewhat.

Scales for Reporting Student Achievement

TIMSS reports trends in student achievement in both mathematics and science and, to provide additional information for improving curriculum and instruction, reports also on student achievement in the major content domains of each subject. To complement the information provided by the content domain scales, TIMSS intends to report how students perform on the cognitive domains of mathematics and science as well as by content.

As each student's achievement booklet contains only a sample of items from the assessment, student responses are combined for an overall picture of the assessment results for each country. Using item response theory (IRT) methods,[1] individual student responses to the items related to mathematics and science are placed on common scales that link to TIMSS results from 1995, 1999, and 2003. At the eighth grade, the TIMSS 2007 mathematics scale allows countries that participated in

1 For a description of the TIMSS scaling techniques as applied to the 2003 data, see Gonzalez, E., Galia, J., & Li, I. (2004). Scaling methods and procedures for the TIMSS 2003 mathematics and science scales. In M.O. Martin, I.V.S. Mullis, & S.J. Chrostowski (Eds.), *TIMSS 2003 technical report*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

TIMSS in 1995, 1999, or 2003 to track their progress in mathematics achievement, and a comparable science scale provides the same information for science. At the fourth grade, the TIMSS 2007 mathematics and science scales link to 1995 and 2003 but not 1999, since the TIMSS 1999 assessment did not include fourth grade.

In addition to the achievement scales for mathematics and science, TIMSS constructs scales for reporting student performance in each of the mathematics and science content domains. In mathematics at the eighth grade there are four content scales, corresponding to the four content domains in TIMSS 2007:

- Number
- Algebra
- Geometry
- Data and Chance

Eighth-grade science in TIMSS 2007 also has four content domain scales:

- Biology
- Chemistry
- Physics
- Earth Science

At fourth grade, TIMSS 2007 has three content domain scales in mathematics:

- Number
- Geometric Shapes and Measures
- Data Display

Fourth-grade science in TIMSS 2007 also has three content domain scales:

- Life Science
- Physical Science
- Earth Science

As described earlier, the TIMSS 2007 frameworks specify three cognitive domains covering mathematics and science at both fourth and eighth grades. The three domains, knowing, applying, and reasoning, describe a range of cognitive processes involved in working in mathematics and science through the primary and middle school years. Reporting scales are constructed for each of the three domains in mathematics and science at both fourth and eighth grades.

Releasing Assessment Material to the Public

The data collection in 2007 is the fourth in the TIMSS series of regular four-year studies, and provides data on trends in mathematics and science achievement since 1995, 1999, and 2003. TIMSS will be administered again in 2011, 2015, and so on into the future. The design provides for releasing many of the items into the public domain as the international reports are published, while safeguarding the trend data by keeping secure a substantial proportion of the items. As items are released, new items will be developed to take their place.

According to the TIMSS 2007 design, six of the 14 assessment blocks in each subject will be released when the assessment results for 2007 are published, and the remaining eight will be kept secure for use in later assessments. The released blocks will include the two blocks containing trend items from 1999,[2] two of the blocks of trend items from 2003, and two blocks of items used for the first time in 2007. The released items will be replaced with new items before the next survey cycle, in 2011.

2 Because TIMSS did not assess fourth-grade students in 1999, the TIMSS 2007 fourth-grade released blocks comprise four blocks of items from 2003 and two from 2007.

Background Questionnaires

An important purpose of TIMSS is to study the educational context in which students learn mathematics and science. To that end, TIMSS will administer questionnaires to curriculum specialists, and to the students in participating schools, their mathematics and science teachers, and their school principals. The questions are designed to measure key elements of the curriculum as it is intended, as it is implemented, and as it is learned.

Curriculum Questionnaires

The mathematics and science curriculum questionnaires are designed to collect basic information about the organization of the mathematics and science curriculum in each country, and about the content of these subjects intended to be covered up to the fourth and eighth grades. The National Research Coordinator in each country is responsible for completing the questionnaires, drawing upon the knowledge and expertise of curriculum specialists and educators as necessary.

Student Questionnaire

This questionnaire is completed by each student who takes the TIMSS assessment. It asks about aspects of students' home and school lives, including classroom experiences; self-perception and attitudes about mathematics and science; homework and out-of-school activities; computer use; home educational supports; and basic demographic information. The questionnaire requires about 30 minutes to complete.

Teacher Questionnaires

In each school participating at the eighth grade, one or more eighth-grade mathematics classes are sampled to take part in the TIMSS testing. The mathematics teachers of these classes complete a mathematics teacher questionnaire, providing information on the teachers' background, beliefs, attitudes, educational preparation, and teaching load, as well as details of the pedagogic approach used in those classes. The science teacher (or teachers) of the students in those classes complete a science teacher questionnaire, which in many respects parallels the mathematics teacher questionnaire. Both questionnaires ask about characteristics of the classes tested in TIMSS; instructional time, materials, and activities for teaching mathematics and science and promoting students' interest in the subjects; use of computers and the internet; assessment practices; and home-school connections. They also ask teachers their views on their opportunities for collaboration with other teachers and professional development, and for information about themselves and their education and training.

At the fourth grade, a single teacher questionnaire containing questions about mathematics and science instruction and about the teachers' background is completed by the classroom teacher of each sampled fourth grade class. The teacher questionnaires require 30-45 minutes of the teachers' time.

School Questionnaire

The principal of each school in TIMSS completes this questionnaire. It asks about enrollment and staffing; resources available to support mathematics and science instruction; school goals and the role of the principal; instructional time; home-school connections; and school climate. It is designed to take about 30 minutes.

Endnotes

The following is a partial list of works that were consulted in the preparation of the mathematics, science, and contextual frameworks.

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Appendix A
Acknowledgements

The TIMSS & PIRLS International Study Center at Boston College

The TIMSS & PIRLS International Study Center (ISC) at Boston College is dedicated to conducting comparative studies in educational achievement. Principally, it serves as the International Study Center for IEA's studies in mathematics, science, and reading – the Trends in International Mathematics and Science Study (TIMSS), and the Progress in International Reading Literacy Study (PIRLS). The staff at the TIMSS & PIRLS ISC is responsible for the design and implementation of these studies. In developing and producing the TIMSS frameworks, ISC staff conducted a collaborative effort involving a series of iterative reviews by the TIMSS 2007 Science and Mathematics Item Review Committee and the National Research Coordinators. The following individuals were instrumental in this process.

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National Research Coordinators

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Appendix B
Example Mathematics Items

Example Mathematics Items

Grade 4

1

Here is a number pattern.

100, 1, 99, 2, 98, □, □, □

What three numbers should go in the boxes?

*Ⓐ 3, 97, 4

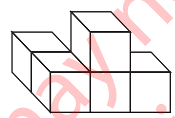
Ⓑ 4, 97, 5

Ⓒ 97, 3, 96

Ⓓ 97, 4, 96

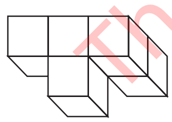
2

This figure will be turned to a different position.

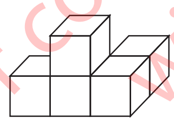


Which of these could be the figure after it is turned?

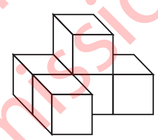
*Ⓐ



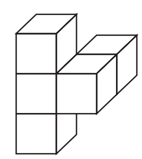
Ⓑ



Ⓒ



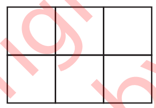
Ⓓ

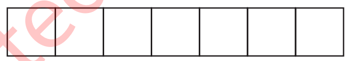


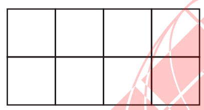
*Correct Answer

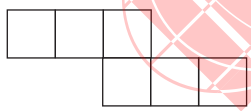
3

Which of these figures has the largest area?

Ⓐ 

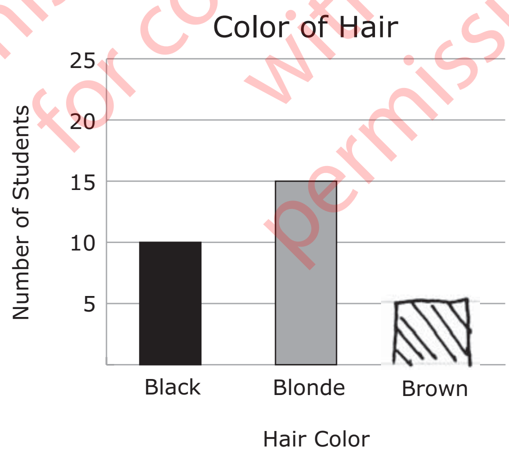
Ⓑ 

*Ⓒ 

Ⓓ 

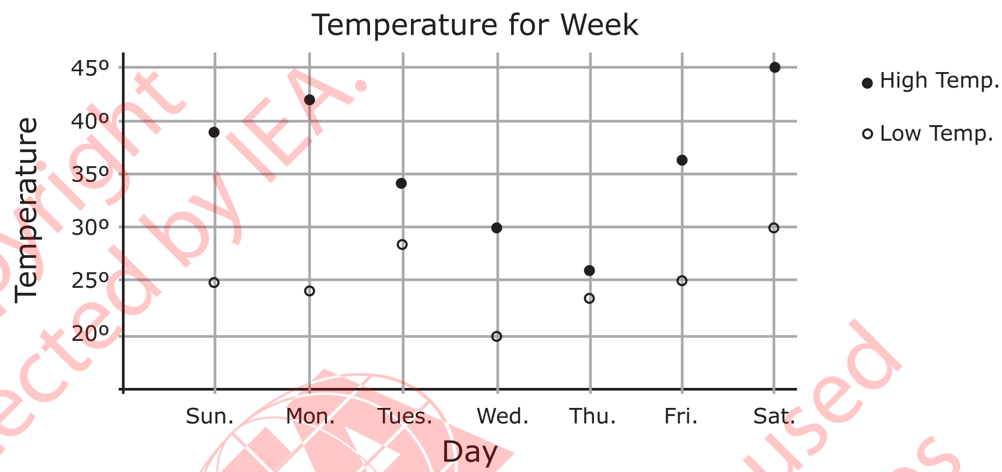
4

In a class of 30 students, 10 have black hair, 15 have blonde hair, and the rest have brown hair. Complete the graph below to show the number of students with brown hair.



*Correct Answer

5



The graph above shows the daily high and low temperatures for a week.

On which day is the difference between the high and low temperatures the greatest?

*(A) Monday

(B) Thursday

(C) Friday

(D) Saturday

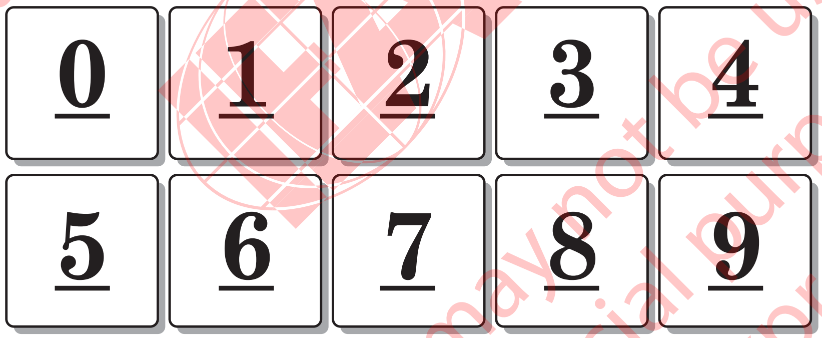
*Correct Answer

Number Tiles

Instructions: Questions **6**, **7**, **8** are about Number Tiles. To answer these questions you may refer to any information shown on the pages in the Number Tiles section.

For this item, you have been given a piece of cardboard with 10 square number tiles like the ones shown below. Take the piece of cardboard and punch out the 10 tiles.

If you do not have the piece of cardboard raise your hand.



Questions for Number Tiles begin on the next page.

Get to 20 Number Game

Two children, Joan and Herbert, are learning to play a game "Get to 20." Here are the rules for the game.

GET TO 20
RULES

Pick Tiles: Each player draws three number tiles.

Add Tiles: Each player places the three tiles to make an addition problem with the sum total closest to 20.

For example, here are four ways a player who draws $\boxed{1}$, $\boxed{4}$, and $\boxed{5}$ could place the tiles:

$$\begin{array}{r} \boxed{5}\boxed{1} \\ +\ \boxed{4} \\ \hline 55 \end{array} \quad \textbf{or} \quad \begin{array}{r} \boxed{4}\boxed{5} \\ +\ \boxed{1} \\ \hline 46 \end{array} \quad \textbf{or} \quad \begin{array}{r} \boxed{1}\boxed{5} \\ +\ \boxed{4} \\ \hline 19 \end{array} \quad \textbf{or} \quad \begin{array}{r} \boxed{1} \\ +\ \boxed{5} \\ +\ \boxed{4} \\ \hline 10 \end{array}$$

This player should choose to show the addition problem $\begin{array}{r} 15 \\ +4 \\ \hline 19 \end{array}$ because 19 is the total closest to 20.

This Number Tiles question continues on the next page.

6

Joan and Herbert played the game "Get to 20."

Joan picked $\boxed{2}$, $\boxed{7}$, and $\boxed{9}$. Herbert picked $\boxed{1}$, $\boxed{3}$, and $\boxed{6}$.

A. What is the addition problem that Joan could make with her number tiles that gives a total closest to 20? Be sure to include the total.

$$\begin{array}{r} 2 \\ +7 \\ +9 \\ \hline 18 \end{array}$$

that would be the closest

B. What is the addition problem that Herbert could make with his number tiles that gives a total closest to 20? Be sure to include the total.

$$\begin{array}{r} 13 \\ +6 \\ \hline 19 \end{array}$$

that would be the closest

C. Herbert said, "If I pick $\boxed{1}$, $\boxed{4}$, and $\boxed{6}$, I can make 20 two different ways."

Show two ways Herbert could make 20 with $\boxed{1}$, $\boxed{4}$, and $\boxed{6}$.

First way:

$$\begin{array}{r} 14 \\ +6 \\ \hline 20 \end{array}$$

Second way:

$$\begin{array}{r} 16 \\ +4 \\ \hline 20 \end{array}$$

Questions for Number Tiles continue.

7

Finding the Largest Number Game

Using the number tiles, Joan and Herbert played a new game. They placed the numbers to make the largest answer.

A. Use the tiles $\boxed{1}$, $\boxed{5}$, and $\boxed{9}$. Write the numbers on the tiles in the boxes below to make the largest answer when you add.

$$\begin{array}{r} \boxed{9}\,\boxed{5} \\ +\quad \boxed{1} \\ \hline 9\ \ 6 \end{array}$$

B. Use the tiles $\boxed{2}$, $\boxed{3}$, and $\boxed{7}$. Write the numbers on the tiles in the boxes below to make the largest answer when you subtract.

$$\begin{array}{r} \boxed{7}\,\boxed{3} \\ -\quad \boxed{2} \\ \hline 7\ \ 1 \end{array}$$

This Number Tiles question continues on the next page.

8

C. Use the tiles $\boxed{1}$, $\boxed{4}$, and $\boxed{5}$. Write the numbers on the tiles in the boxes below to make the largest answer when you multiply.

$$\begin{array}{r} \boxed{4}\,\boxed{1} \\ \times \quad \boxed{5} \\ \hline 205 \end{array}$$

End of Number Tiles section.

Example Mathematics Items

Grade 8

1

If n is a negative integer, which of these is the largest number?

Ⓐ $3 + n$

Ⓑ $3 \times n$

*Ⓒ $3 - n$

Ⓓ $3 \div n$

2

In a car rally two checkpoints are 160 km apart. Drivers must travel from one checkpoint to the other in exactly 2.5 hours to earn maximum points.

A. What must the average speed be to travel the 160 km in this time?

Answer: 64 kph

$2.5\overline{)160}$ = 64

14
3.5
12
3

2.5
5
7.5
10

B. A driver took 1 hour to travel through a 40 km hilly section at the beginning of the course.

What must the average speed, in kilometers per hour, be for the remaining 120 km if the total time between checkpoints is to be 2.5 hours?

Answer: 80 kph

$1.5\overline{)120}$ = 80

8
4
12

1 h — 1.5 h
40 km — 120 km — 160 km

*Correct Answer

3

The three figures below are divided into small congruent triangles.

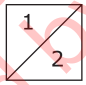


Figure 1

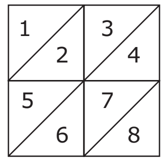


Figure 2

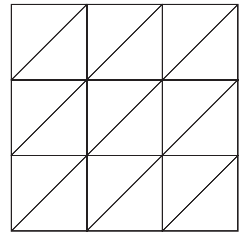


Figure 3

A. Complete the table below. First, fill in how many small triangles make up Figure 3. Then, find the number of small triangles that would be needed for the 4th figure if the sequence of figures is extended.

Figure	Number of Small Triangles
1	2
2	8
3	18
4	32

B. The sequence of figures is extended to the 7th figure. How many small triangles would be needed for Figure 7?

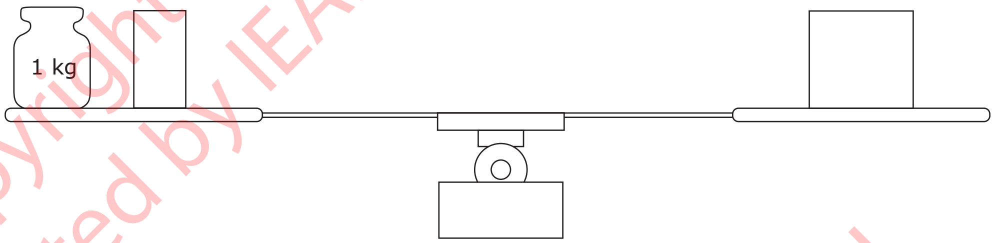
Answer: 98

C. The sequence of figures is extended to the 50th figure. Explain a way to find the number of small triangles in the 50th figure that does not involve drawing it and counting the number of triangles.

multiply the figure by itself and then multiply the answer you get by two.

4

The objects on the scale make it balance exactly. On the left pan there is a 1 kg weight (mass) and half a brick. On the right pan there is one brick.



What is the weight (mass) of one brick?

Ⓐ 0.5 kg

Ⓑ 1 kg

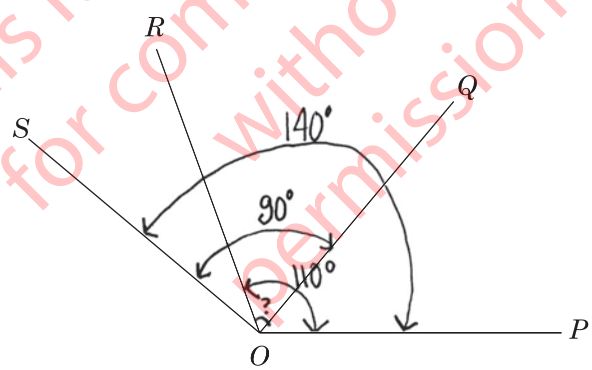
*Ⓒ 2 kg

Ⓓ 3 kg

M012002

5

In the figure, the measure of $\angle POR$ is 110°, the measure of $\angle QOS$ is 90°, and the measure of $\angle POS$ is 140°.



What is the measure of $\angle QOR$?

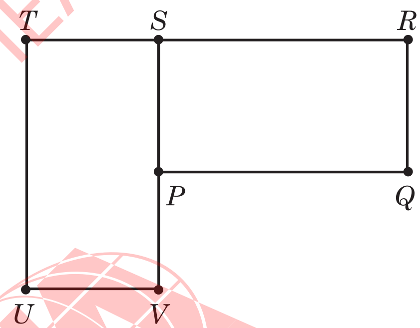
140 − 110 = 30
90 − 30 = 60

Answer: 60°

*Correct Answer

6

Rectangle $PQRS$ can be rotated (turned) onto rectangle $UVST$.



What point is the center of rotation?

Ⓐ P

Ⓑ R

*Ⓒ S

Ⓓ T

Ⓔ V

*Correct Answer

Phone Plans

Instructions: Questions 7, 8, 9 are about Phone Plans.
To answer these questions you may refer to any information shown on the pages in the Phone Plans section.

Betty, Frank, and Darlene have just moved to Zedland. They each need to get phone service. They received the following information from the telephone company about the two different phone plans it offers.

They must pay a set fee each month and there are different rates for each minute they talk. These rates depend on the time of the day or night they use the phone, and on which payment plan they choose. Both plans include time for which phone calls are free. Details of the two plans are shown in the table below.

Plan	**Monthly Fee**	**Rate per minute**		**Free minutes per month**
		Day (8 am – 6 pm)	Night (6 pm – 8 am)	
Plan A	20 zeds	3 zeds	1 zed	180
Plan B	15 zeds	2 zeds	2 zeds	120

7 Betty talks for less than 2 hours per month. Which plan would be less expensive for her?

Less expensive plan B

Explain your answer in terms of both the monthly fee and free minutes.

2 hours = 120 min. Only uses the free minutes

A: 20 + 0 = 20

B: 15 + 0 = 15 Cheaper

Questions for Phone Plans continue.

8

Frank talks for 5 hours per month at the night rate. What would each plan cost him per month? Show your work.

Cost Per Month for Plan A: 140 zeds

Cost Per Month for Plan B: 375 zeds

5 hrs = 5 x 60 = 300 min

A: 300 − 180 = 120 min
120 x 1 = 120 zeds
120 + 20 = 140 zeds.

B: 300 − 120 = 180 min
180 x 2 = 360 zeds.
360 + 15 = 375 zeds.

Questions for Phone Plans continue.

9

Darlene signed up for the *Plan B*, and the cost of one month of service was 75 zeds. How many minutes did she talk that month? Show your work.

Minutes talked 150

75 − 15 = 60 zeds
60 : 2 = 30 minutes
30 + 120 = 150 minutes

End of Phone Plans section.

Appendix C
Example Science Items

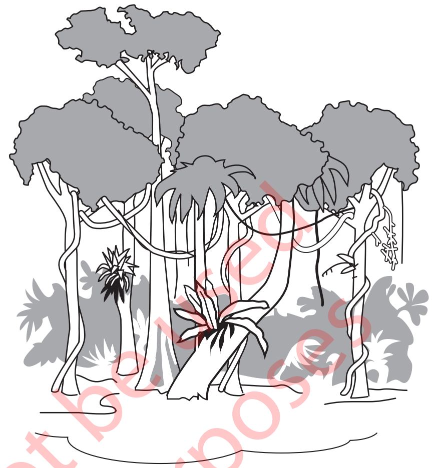
Example Science Items

Grade 4

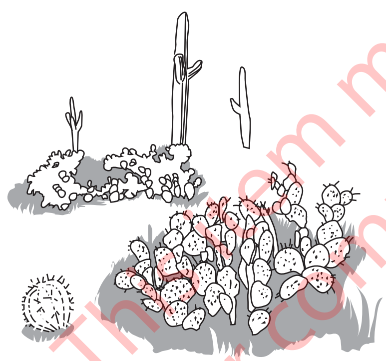
1 Which of these types of plants are usually found growing in a tropical rain forest?

Ⓐ

*Ⓑ



Ⓒ

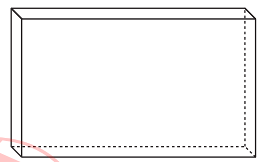


Ⓓ

*Correct Answer

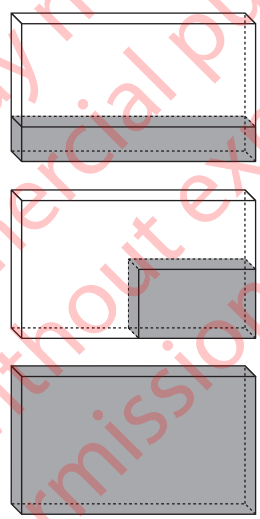
2

The figure **above** shows a box that contains a material that could be a solid, a liquid or a gas. The material is then put into a box four times as large.



Look at the figures **below**. They show how the different types of material will look when put into the larger box.

A. Identify which figure shows a solid, which shows a liquid and which shows a gas. (Write the word *solid*, *liquid* or *gas* on the line next to each figure below. Use each word only once.)



liquid

solid

gas

B. Explain your answers.

Liquid is runny so it finds the lowest place in the box.

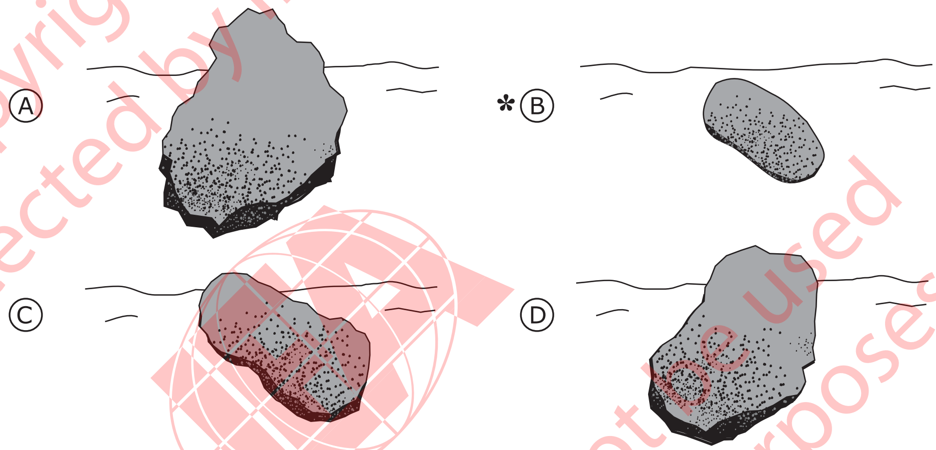
A solid can be everywhere in the box but it stays the same shape.

A gas takes up all the room it wants.

3

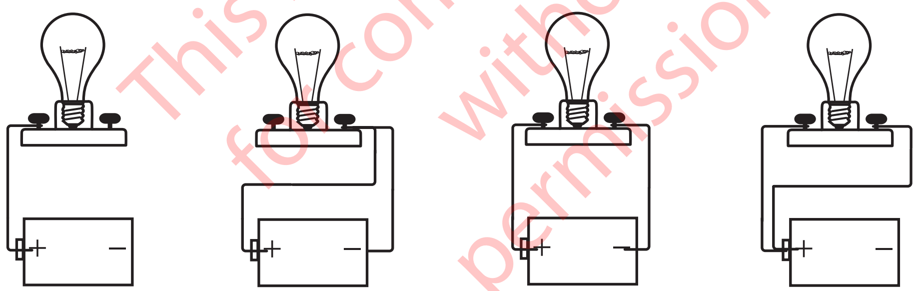
Lily found four rocks of the same material in a riverbed. They had different shapes and sizes.

Which rock has most likely been carried the farthest down the river?



4

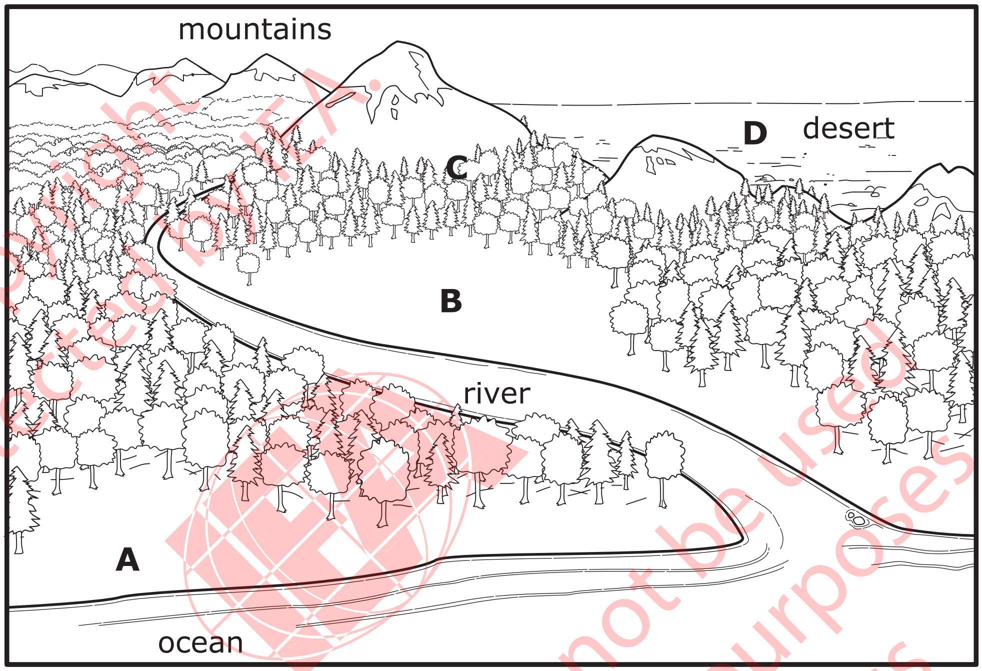
The pictures show a lightbulb connected to a battery.
Which bulb will light?



(A) (B) *(C) (D)

*Correct Answer

5



Look at the picture above. Where is the best location to grow crops?

Ⓐ Location A

*Ⓑ Location B

Ⓒ Location C

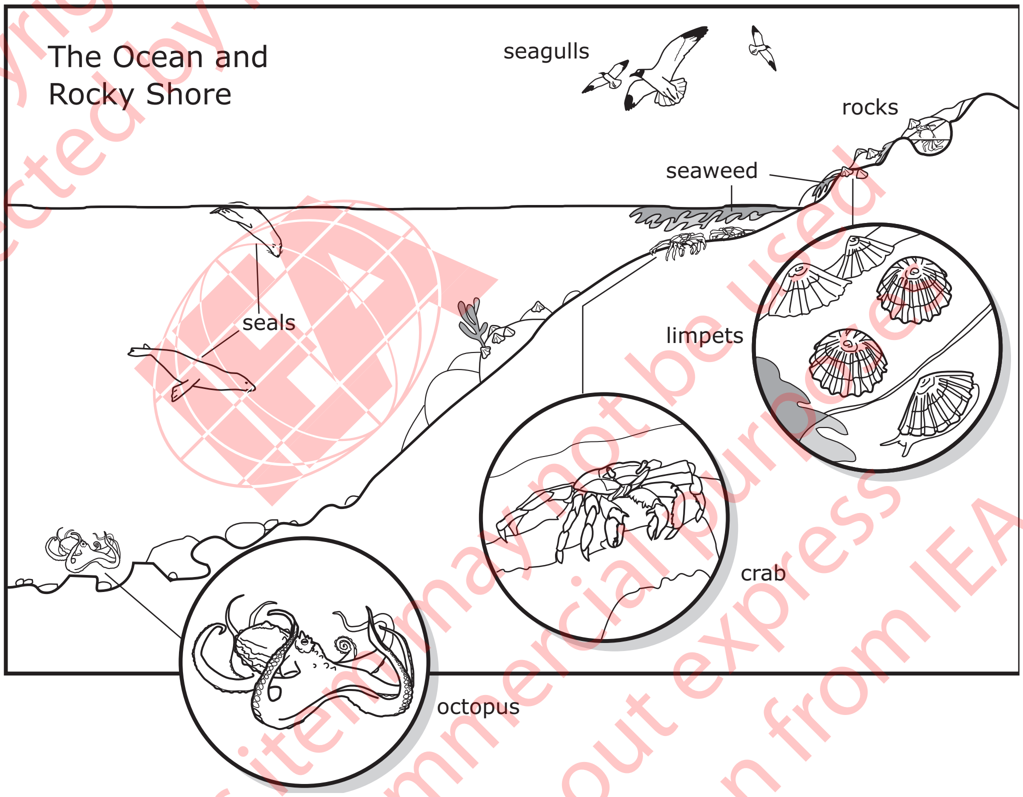
Ⓓ Location D

*Correct Answer

6

Ocean Food Chain

The picture below shows part of an ocean and some of the organisms (plants and animals) that live in and around the ocean.

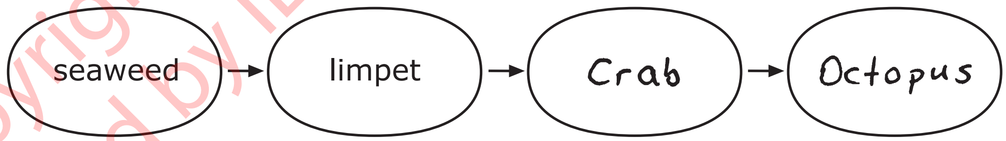


Look at the list of living organisms (plants and animals) below. The table gives information about what each organism in the picture of the ocean needs for food.

Name of Organism	What the Organism Needs for Food
Seaweed	Sunlight to make its own food
Limpet	Seaweed
Crab	Limpets
Octopus	Limpets, crabs, and fish
Seagull	Crabs and fish
Seal	Crabs, octopus and fish

Questions for Ocean Food Chain begin on the next page.

The diagram below shows part of a food chain. The arrows go from one organism to another organism that eats it. In this food chain, the limpets eat seaweed.



A. Complete the food chain **above** by writing the names of two other organisms from the table in the blank spaces. Use the information in the table about what each organism needs for food.
(There is more than one correct food chain. You need to show just one.)

B. One year a disease causes many limpets to die. What would happen to the **seaweed** in your food chain when the limpets die?

The amount of seaweed will grow because there isn't lots of limpets to eat it.

C. Choose another organism in your food chain (not seaweed or limpet).

Name of organism: Crab

What would happen to this organism when the limpets die?

Some crabs will die because there isn't a lot of limpets to eat.

D. What would happen to the other organisms in your food chain if the seaweed does not grow well?

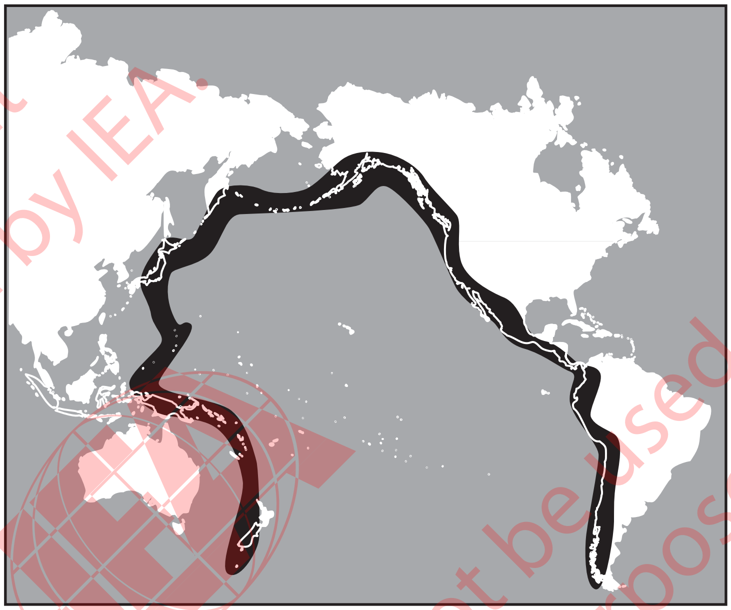
The limpets will starve, so some crabs will die, so some octopuses will die. If one tiny thing happens to an animal or plant, it can affect the whole food chain.

End of Ocean Food Chain questions.

Example Science Items

Grade 8

1



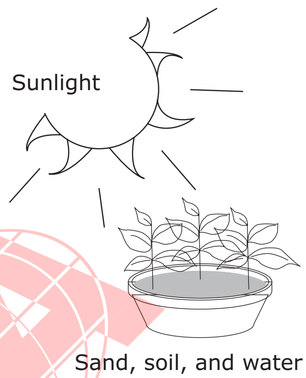
The diagram above shows the Pacific Ring of Fire. Earthquakes and volcanic activity occur along the Ring of Fire. Which of the following best explains why?

* Ⓐ It is located at the boundaries of tectonic plates.
Ⓑ It is located at the boundary of deep and shallow water.
Ⓒ It is located where the major ocean currents meet.
Ⓓ It is located where ocean temperature is the highest.

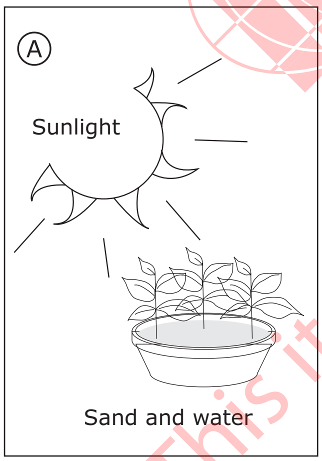
*Correct Answer

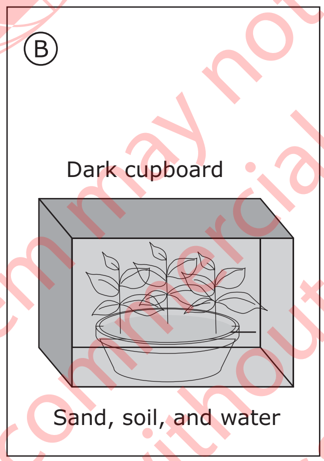
2

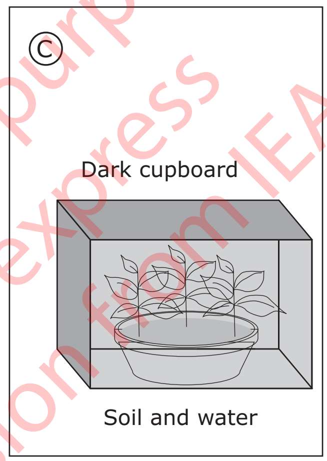
A girl has an idea that green plants need sand in the soil for healthy growth. In order to test her idea she uses two pots of plants. She sets up one pot of plants as shown below.

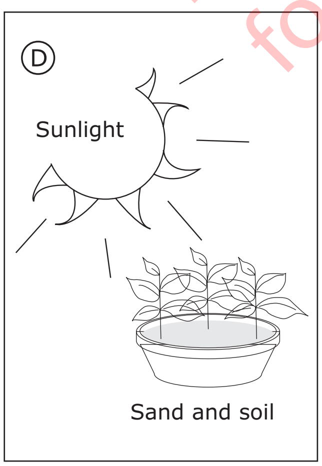


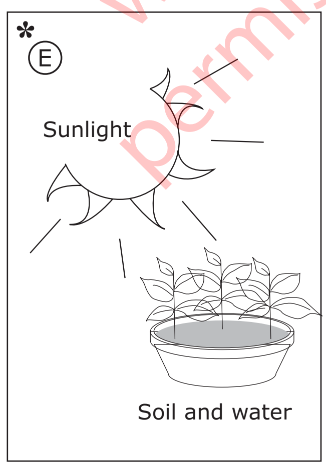
Which ONE of the following should she use for the second pot of plants?











*Correct Answer

3

The picture shows how a student set up some apparatus in a laboratory for an investigation. The inverted test tube was completely filled with water at the beginning of the investigation as shown in Figure 1. After several hours, the level of water in the test tube had gone down as shown in Figure 2.

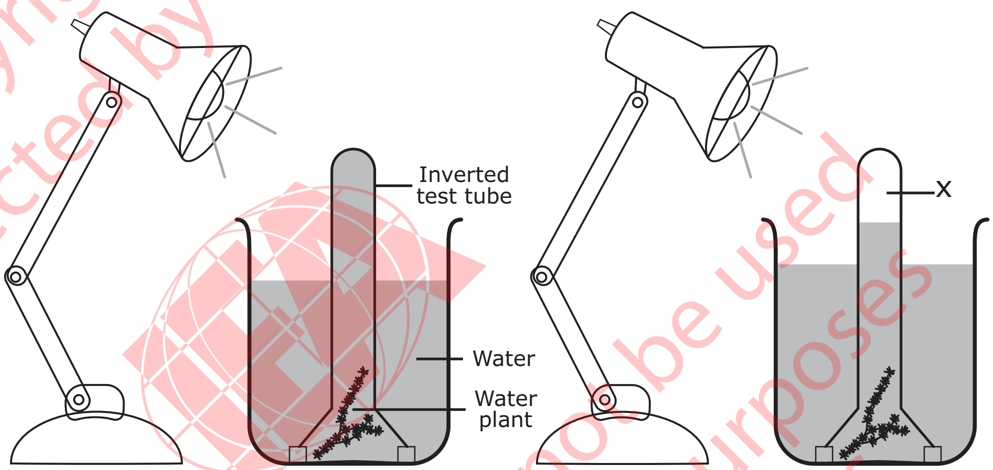


Figure 1

Figure 2

What is contained in the top part of the test tube labeled X in Figure 2?

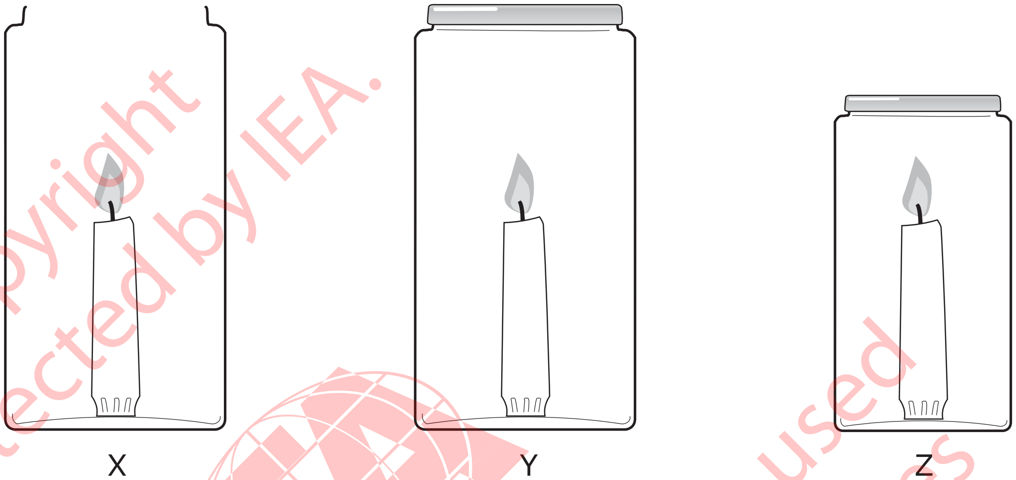
(Check one box.)

- ☐ air
- ☑ oxygen
- ☐ carbon dioxide
- ☐ vacuum

Explain your answer.

During photosynthesis, plants produce oxygen and glucose.

4



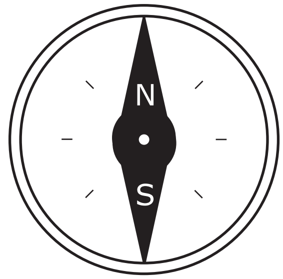
Three identical candles are placed in the three jars shown above and lit at the same time. Jars Y and Z are then sealed with lids, and Jar X is left open.

Which candle flame will go out first (X, Y, or Z)? Z

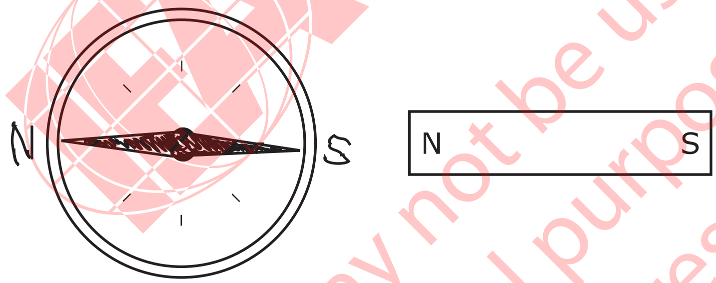
Explain your answer.

Z because fire needs oxygen to stay lit. With the lid being sealed no oxygen can get in. There is a little bit of air in there for it to stay lit. Since Z is smaller than Y, Z would go out first.

5



The diagram above shows a compass needle with its North and South poles labeled (N and S). It is placed next to a strong magnet as shown in the diagram below.



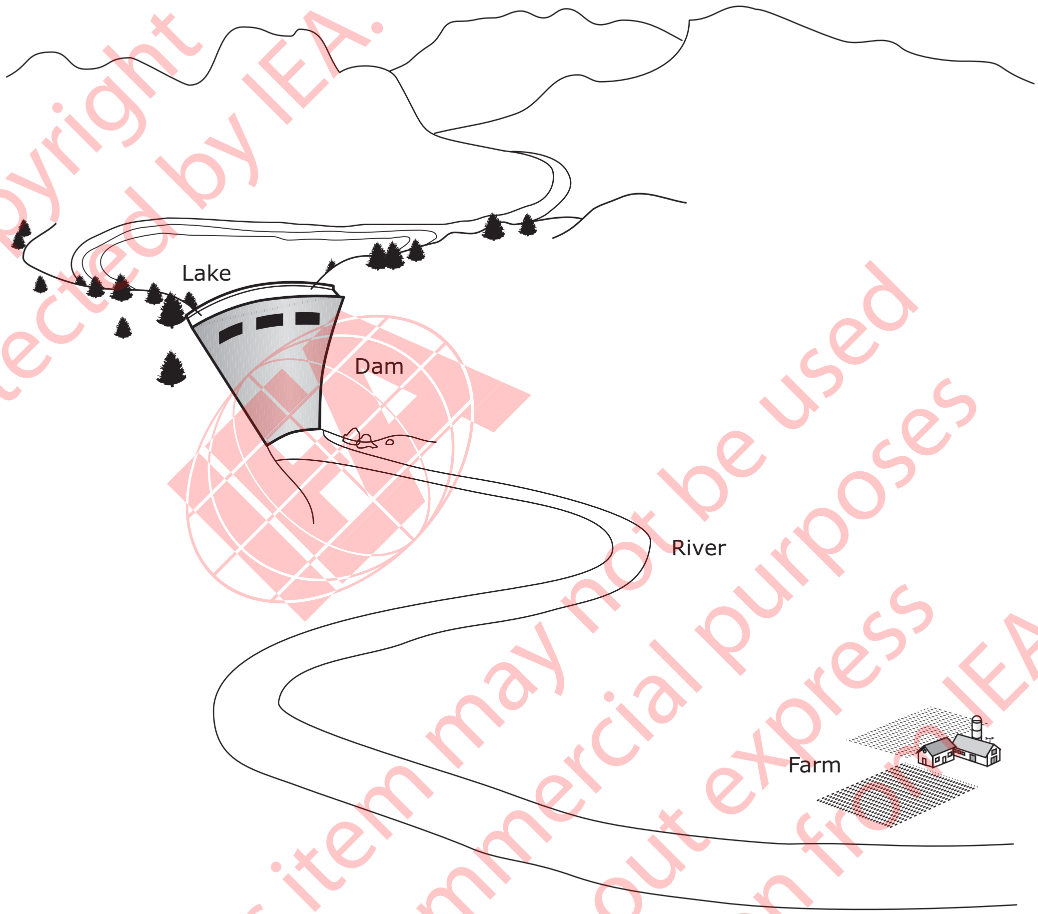
A. Draw the compass needle in the circle on the diagram above.
   Label the North (N) and South (S) poles of the needle.

B. Explain your answer using your knowledge of magnets.

The north pole on the magnet will attract the south pole. on the compass

6

The diagram shows a farm in a valley where a dam has just been built.



The presence of the dam can have both positive and negative effects on farming in the valley.

A. Describe one positive effect of the dam on farming.

The dam will stop the water from flooding the field.

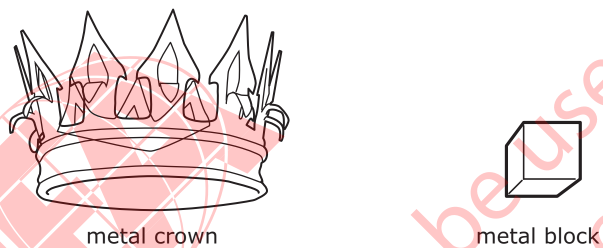
B. Describe one negative effect of the dam on farming.

Less irrigation because the dam may not let enough water flow through.

Metal Crown

Instructions: Questions **7**, **8**, **9**, **10** are about Metal Crown. To answer these questions you may refer to any information shown on the pages in the Metal Crown section.

A king gave a jeweler a block of pure metal. He asked the jeweler to make him a crown out of the metal.



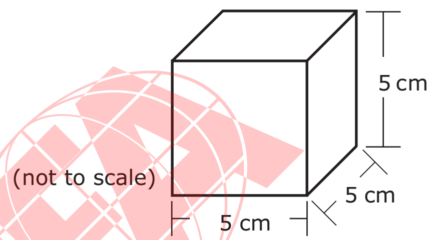
After the jeweler delivered the crown, the king observed it carefully. He thought that the jeweler might have substituted another pure metal or a mixture of metals to make the crown. He weighed the crown, and it had the same mass as the original block, 2400 grams. Still not satisfied, the king asked some scientists to help him find out what the crown was made of.

Questions for Metal Crown begin on the next page.

7

The scientists decided to compare the densities of the crown and a block of metal just like the originalblock. The density of a substance is the mass of a sample of the substance divided by its volume (density = mass/volume).

The scientists found the volume of the block and computed its density based on its known mass (2400g). The diagram below shows the dimensions of the block of metal that the scientists measured.



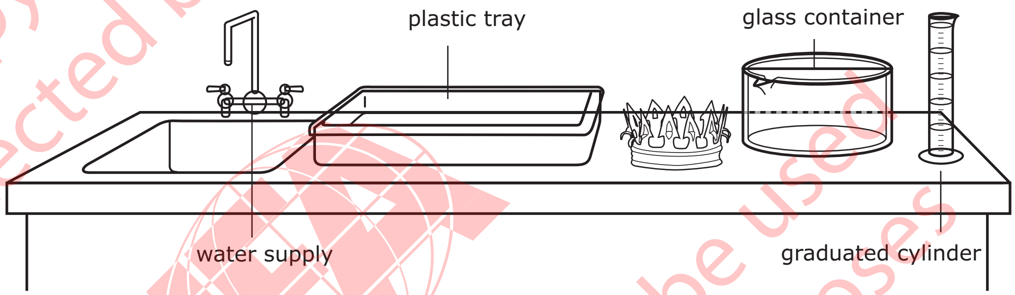
What is the density of the block of metal?

Answer: 19.2 g/cm^3

Questions for Metal Crown continue.

8

The scientists then needed to find the volume of the crown in order to determine its density. The following equipment and materials were available for them to use.



Describe a procedure that the scientists could use to find the volume of the crown using some or all of the equipment and materials shown above. You may use diagrams to help explain your procedure.

Fill the beaker with enough water to cover the crown. Add the crown and mark the side of the beaker where the water level is. Then take the crown out. Use the graduated cylinder to add little bits of water until the level comes back up to the mark. That is the Volume of the crown.

Questions for Metal Crown continue.

9

The scientists measured the volume of the crown five times. They computed the density for each volume measurement. Their results are shown in the table below.

Trial	Volume of Crown (cm^3)	Density of Crown (g/cm^3)
1	202	11.88
2	200	12.00
3	201	11.94
4	198	12.12
5	199	12.06

A. Why did the scientists measure the volume five times?

Because there is experimental error. So, measuring it 5 times you can calculate the average to know how much error there is.

B. The scientists reported to the king that the density of the crown was 12.0 g/cm^3. Show how the scientists used their results to obtain this value for the density.

They added together all of the densities and then divided by 5 to get the average.

Questions for Metal Crown continue.

10

The table below lists the density for different metals.

Metal	Density (g/cm^3)
Platinum	21.4
Gold	19.3
Silver	10.5
Copper	8.9
Zinc	7.1
Aluminum	2.7

A. Look at the density you computed for the block of metal. What was the block of metal most likely made of?

Answer: Gold

Explain your answer.

It had the closest density.

B. The density of the crown was found to be 12.0 g/cm^3. What would you report to the king about what metal or mixture of metals the jeweler used to make the crown?

The jeweler used some silver as well as gold.

End of Metal Crown section.

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