Profiles of student achievement in science at the TIMSS international benchmarks: U.S. performance and standards in an international context

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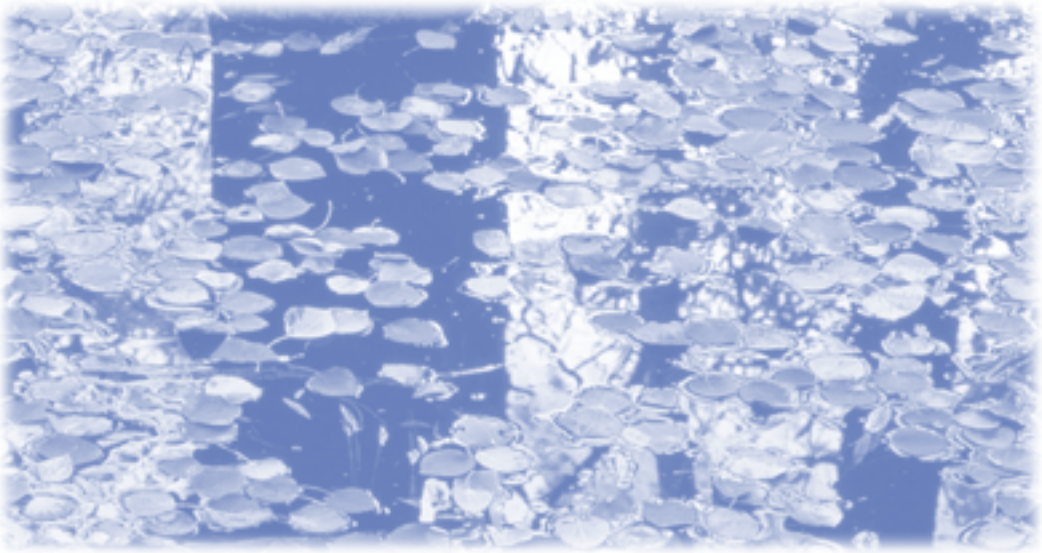

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Profiles of Student Achievement in Science at the TIMSS International Benchmarks:
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The panel that developed the TIMSS benchmarks — Susan Agruso, Audrey Champagne, Lee Jones, Christine O'Sullivan, Senta Raizen, Galina Kovalyova, Im Hyung, Jan Lokan, and Jana Strakova — played a critical role in the scale anchoring analysis. Without their expertise and the energy they devoted to reviewing the TIMSS items and drafting descriptions, this report would not have been possible. We also thank United States panel members, Audrey Champagne, Christine O'Sullivan, and Senta Raizen, for their work comparing the TIMSS benchmarks with the *National Science Education Standards*. Their expertise in science education in the United States made the analysis possible. We also would like to thank all of the panel members for the time and energy they spent reviewing the results of the analyses. We would especially like to thank Christine O'Sullivan for her contribution to this report.

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CONTENTS

Introduction

The Third International Mathematics and Science Study (TIMSS) is the largest, most comprehensive, and most rigorous international study of schools and student achievement ever conducted. In 1995, more than 40 countries participated in an assessment of mathematics and science achievement at the fourth, eighth, and twelfth grades.[1] The results of the TIMSS 1995 assessment are available in a series of international reports published by the TIMSS International Study Center at Boston College.[2]

In 1998, the National Science Foundation awarded a grant for the TIMSS International Study Center to conduct an in-depth analysis of the TIMSS 1995 mathematics and science achievement results for fourth and eighth grades. The project had two components: (1) describe what students reaching the TIMSS international benchmarks of achievement know and can do in mathematics and science and begin to develop profiles of "world-class achievement," and (2) compare world-class mathematics and science achievement with U.S. national standards for these subjects.

1 In most countries, the grades tested for TIMSS were grades four, eight, and twelve.

2 Beaton, Martin, Mullis, Gonzalez, Smith & Kelly, 1996; Beaton, Mullis, Martin, Gonzalez, Kelly & Smith, 1996; Martin, Mullis, Beaton, Gonzalez, Smith & Kelly, 1997; Mullis, Martin, Beaton, Gonzalez, Kelly & Smith, 1997; and Mullis, Martin, Beaton, Gonzalez, Kelly, and Smith, 1998.

The purpose of the first part of the study was to interpret the TIMSS scale scores and analyze achievement at different points on the TIMSS scales. This was accomplished by conducting a scale anchoring analysis to describe achievement of students reaching four points on each of the TIMSS mathematics and science scales — the Top 10%, Upper Quarter, Median, and Lower Quarter international benchmarks (90th, 75th, 50th, and 25th international percentiles). Panels of mathematics and science educators examined the TIMSS items and identified what students reaching each benchmark know and can do.

For the second part of the study, the descriptions of performance at the benchmarks provided the basis for examining mathematics and science standards in the United States. The panels compared achievement at the benchmark levels with two prominent sets of standards for mathematics and science education — the National Council of Teachers of Mathematics' (NCTM) *Principles and Standards for School Mathematics* and the National Research Council's *National Science Education Standards* (NSES).[3]

This report presents detailed information about the science achievement of fourth- and eighth-grade students in the countries that participated in TIMSS in 1995, and how that achievement aligns with the science standards. A companion volume, *Profiles of Student Achievement in Mathematics at the TIMSS International Benchmarks: U.S. Performance and Standards in an International Context*, presents the analysis of TIMSS mathematics achievement in 1995 and compares it with the mathematics standards.

3 National Council of Teachers of Mathematics (2000) and National Research Council (1995).

Overview

International Benchmarks of Science Achievement

Overview — International Benchmarks

International
Benchmarks of Science Achievement

As the United States continues to work to improve science education, educators, curriculum developers, and policymakers need to know what students know and can do in science and how they compare with students around the world. TIMSS provides detailed information about what students around the world know and can do in science overall as well as in specific science content areas, such as physical science, life science and earth science. TIMSS also provides cross-national comparisons, enabling the United States to view its performance in an international context.

To provide benchmarks by which to compare countries' performance, achievement on TIMSS was reported at four empirically-derived benchmarks on the TIMSS scales – the Top 10% benchmark, the Upper Quarter benchmark, the Median benchmark, and the Lower Quarter benchmark. These benchmarks mark the performance of the top 10%, top quarter, top half, and top three-quarters of students in the countries participating in TIMSS.[1]

1 The TIMSS international reports gave results for the 90th, 75th, and 50th international percentiles; these as well as those for the 25th international percentiles are included in this report.

To describe these benchmarks in terms of what students reaching them know and can do, the TIMSS International Study Center conducted an in-depth analysis to determine the science content knowledge and understandings associated with each benchmark for fourth and eighth grades. Together, the benchmark descriptions and the percentages of students in each country reaching each international benchmark show the strengths and weaknesses of fourth and eighth graders in the TIMSS countries. Moreover, by articulating performance at the TIMSS international benchmarks, "world class" achievement has been defined.

Developing Benchmarks of Science Achievement

To develop descriptions of achievement at the TIMSS international benchmarks, TIMSS used the scale anchoring method.[2] Scale anchoring is a way of describing students' performance at different points on a scale in terms of what students know and can do. It involves a statistical component in which items that discriminate between successive points on the scale are identified and a judgmental component in which subject-matter experts examine the items and generalize to students' knowledge and understandings.

First, the TIMSS assessment results were used to identify the items that students reaching each international benchmark are likely to answer correctly and that students at the next lower benchmark are unlikely to answer correctly. Criteria were applied to group the items by benchmark level. For example, for the Top 10% benchmark, an item was included for the benchmark if at least 65 percent of students scoring at that scale point answered the item correctly and less than 50 percent of students scoring at the Upper Quarter benchmark answered the item correctly. Similarly, for the Upper Quarter benchmark, an item was included if at least 65 percent of students scoring at that point answered the item correctly and less than 50 percent of students at the Median benchmark answered the item correctly. The application of these criteria resulted in sets of items representing accomplishments of students reaching each benchmark.

2 | The analysis is fully documented in Kelly (1999).

Second, a panel of science educators from the TIMSS countries examined the groups of items and summarized the content knowledge and conceptual understandings of the students reaching each level. The science panel comprised nine individuals (see below) with extensive experience in science education and assessment, as well as a thorough knowledge of the TIMSS Curriculum Frameworks[3] and achievement tests.

The panelists' assignment consisted of three tasks: (1) work through the items one by one and describe what students answering each item correctly know and can do, or what they do to answer the item correctly; (2) based on the items for each benchmark, draft a detailed description of the knowledge, understandings, and skills demonstrated by students; and (3) select TIMSS example items to support and illustrate the benchmark descriptions.

Panel that Developed TIMSS International Benchmarks of Science Achievement

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3 | Robitaille, Schmidt, Raizen, McKnight, Britton, and Nicol (1993).

Fourth- and Eighth-Grade Performance at the TIMSS International Benchmarks of Science Achievement

Six factors appear to distinguish performance at the four benchmarks in science:

- depth and breadth of content area knowledge;
- understanding and use of technical vocabulary;
- context of problem (progressing from practical to more abstract);
- knowledge of scientific investigation;
- complexity of diagrams, graphs, tables, and textual information; and
- completeness of written responses.

At fourth grade, students scoring at the lower end of the scale recognize some elementary facts presented in everyday language and are able to interpret simple diagrams. Their peers scoring at higher levels demonstrate knowledge of an expanded set of science topics; use more tabular, diagrammatic and textual information; and provide written responses communicating knowledge of scientific phenomena. Students scoring at the Top 10% benchmark demonstrate understanding of more complex topics, apply scientific understanding to interpret maps, diagrams and data tables; recognize aspects of scientific investigation; and provide written responses requiring two or more pieces of scientific information.

At eighth grade, students scoring at the lower end of the scale demonstrate an understanding of some basic facts from the earth, life and physical sciences presented using non-technical language; interpret and use information in labeled pictorial diagrams, tables and graphs; and provide short written responses containing a single piece of factual information. Students scoring at higher levels demonstrate knowledge of facts and terminology involving more advanced topics particularly in the areas of physics and chemistry; interpret more representational diagrams; and combine sources of information to draw conclusions and provide brief explanations. Students scoring at the Top 10% benchmark demonstrate understanding of more abstract scientific concepts; apply basic physical principles to develop explanations and make scientific connections; and understand fundamentals of scientific investigation.

Figures 1 and 2 show the summary descriptions of performance at the TIMSS international benchmarks of science achievement for fourth and eighth grades. The figures also show the percentage of students in each country reaching each benchmark, with countries ranked by the percentage reaching the Top 10% benchmark.

These descriptions of performance encapsulate the major accomplishments of students reaching each benchmark. The next two sections of this report provide the detailed descriptions of performance at each benchmark, with items illustrating what students reaching each benchmark know and can do. The language used in the descriptions should be interpreted as appropriate for the grade level. For example, the term "basic" knowledge for fourth grade applies to what is appropriate at that grade level and is not the same as "basic" knowledge at the eighth grade.

Performance on the TIMSS scales is cumulative and the benchmark descriptions must be interpreted accordingly. That is, students reaching a particular benchmark demonstrate the knowledge and understandings characterizing that benchmark as well as the lower benchmarks. It is also important to recognize that some students scoring below a benchmark may indeed know or understand some of the concepts that characterize a higher level. For example, students scoring just below the scale score marking the Top 10% benchmark will have considerable success on the items for that benchmark. Similarly, students scoring above that scale score may not have success on all of the items for the Top 10% benchmark.

U.S. fourth graders performed well compared with their peers around the world. As shown in Figure 1, 16 percent reached the Top 10% benchmark, 35 percent reached the Upper Quarter benchmark, 63 percent reached the Median benchmark, and 85 percent reached the Lower Quarter benchmark. These percentages exceed the international percentages, and only Korea had more fourth-grade students reaching the highest benchmark.

The performance of U.S. eighth graders also somewhat exceeded the international level, with 13 percent reaching the Top 10% benchmark, 30 percent reaching the Upper Quarter benchmark, 55 percent reaching the Median benchmark, and 79 percent reaching the Lower Quarter benchmark.

Interpreting Figures 1 and 2

The percentages of students reaching the TIMSS benchmarks provide a way of interpreting differences in countries' performance on TIMSS. To illustrate, the data in Figure 1 show that 10 percent of all fourth graders in the countries participating in TIMSS achieved a score of 660 or better in science. This score is thus the benchmark for the top 10 percent of fourth-grade students internationally. Similarly, 25 percent of all fourth graders achieved a score of 607 or better in science, and this is the Upper Quarter benchmark, and so on. If all countries had the same performance, then in each country 10 percent of the students would be at or above the Top 10% benchmark, 25 percent would be at or above the Upper Quarter benchmark, half would be at or above the Median benchmark, and 75 percent would be at or above the Lower Quarter benchmark. While some countries achieved nearly this pattern, there was wide variation in the percentages of students reaching the benchmarks. For example, at the fourth grade (Figure 1), 17 percent of students in top-performing Korea reached the Top 10% international benchmark. In other words, almost 20 percent of fourth-graders in Korea performed as well as the top 10 percent of students internationally. In contrast, 1 percent or less of students in Greece, Portugal, Cyprus, Kuwait, Thailand, and Iran reached this benchmark.

FIGURE 1

Percentages of Students Reaching TIMSS International Benchmarks of Science Achievement — Fourth Grade*

	Percentages of Students Reaching International Benchmarks	Top 10%	Upper Quarter	Median	Lower Quarter
Korea		17 (0.9)	46 (1.3)	81 (0.9)	96 (0.4)
United States		16 (0.9)	35 (1.3)	63 (1.4)	85 (0.9)
Australia		14 (0.7)	32 (1.1)	62 (1.3)	85 (1.0)
England		13 (1.0)	28 (1.4)	55 (1.5)	82 (1.1)
Singapore		11 (1.5)	27 (2.1)	54 (2.2)	81 (1.3)
Japan		11 (0.6)	33 (1.0)	68 (1.0)	93 (0.5)
Czech Republic		11 (1.0)	26 (1.4)	58 (1.5)	87 (0.9)
Austria		10 (0.9)	30 (1.6)	64 (1.6)	89 (1.0)
Canada		9 (0.7)	25 (1.5)	55 (1.4)	84 (1.0)
New Zealand		9 (0.9)	22 (1.4)	47 (2.0)	76 (1.9)
Scotland		9 (0.8)	22 (1.4)	50 (1.9)	77 (1.6)
Ireland		7 (0.6)	21 (1.3)	52 (1.7)	82 (1.2)
Slovenia		6 (0.7)	21 (1.4)	54 (1.7)	86 (1.3)
Norway		6 (0.6)	19 (1.2)	47 (1.6)	78 (1.5)
Netherlands		5 (0.6)	23 (1.4)	60 (1.7)	92 (1.0)
Hungary		5 (0.6)	17 (1.3)	48 (1.7)	80 (1.4)
Hong Kong		4 (0.7)	17 (1.4)	48 (1.8)	82 (1.5)
Latvia (LSS)		4 (1.2)	12 (1.7)	34 (2.3)	72 (1.9)
Israel		3 (0.5)	12 (1.0)	34 (1.7)	68 (1.5)
Iceland		3 (0.4)	11 (0.8)	36 (1.5)	68 (1.9)
Greece		1 (0.2)	8 (0.8)	30 (1.5)	67 (1.9)
Portugal		1 (0.2)	5 (0.7)	23 (1.4)	59 (1.9)
Cyprus		1 (0.1)	4 (0.5)	20 (1.4)	56 (1.8)
Kuwait		0 (0.1)	1 (0.1)	5 (0.3)	22 (1.0)
Thailand		0 (0.1)	3 (0.4)	17 (1.9)	55 (2.9)
Iran, Islamic Rep.		0 (0.1)	1 (0.2)	5 (0.9)	25 (2.0)

Top 10% Benchmark (90th Percentile) = 660

Upper Quarter Benchmark (75th Percentile) = 607

Median Benchmark (50th Percentile) = 541

Lower Quarter Benchmark (25th Percentile) = 466

The international benchmarks correspond to the percentiles computed from the combined data from all of the countries participating in 1995.

SOURCE: IEA Third International Mathematics and Science Study (TIMSS), 1994-1995.

FIGURE 1

* Fourth grade in most countries.

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

Summary of Performance at TIMSS International Benchmarks
Science — Fourth Grade

Top 10% International Benchmark

Demonstrate beginning knowledge of plant and animal development, reproduction and heredity; know some basic information related to human physiology; demonstrate beginning knowledge of light properties and energy sources; apply scientific understanding to interpret maps, diagrams and data tables; recognize aspects of scientific investigation; provide written responses requiring two or more pieces of information.

Upper Quarter International Benchmark

Demonstrate some understanding of earth processes and resources; demonstrate some knowledge of structure and function in plants and animals; recognize some basic terminology and chemical and physical properties of familiar materials; apply knowledge to practical situations; provide brief descriptions and explanations of everyday phenomena.

Median International Benchmark

Know some basic facts about earth's water, soil and pollution; recognize basic biological facts and terminology — attributes and habitats of common groups of animals, human life processes and health; demonstrate some understanding of physical concepts in practical contexts– burning, heat and temperature, weight (mass); interpret tabular and diagrammatic information; provide short factual written responses demonstrating practical knowledge.

Lower Quarter International Benchmark

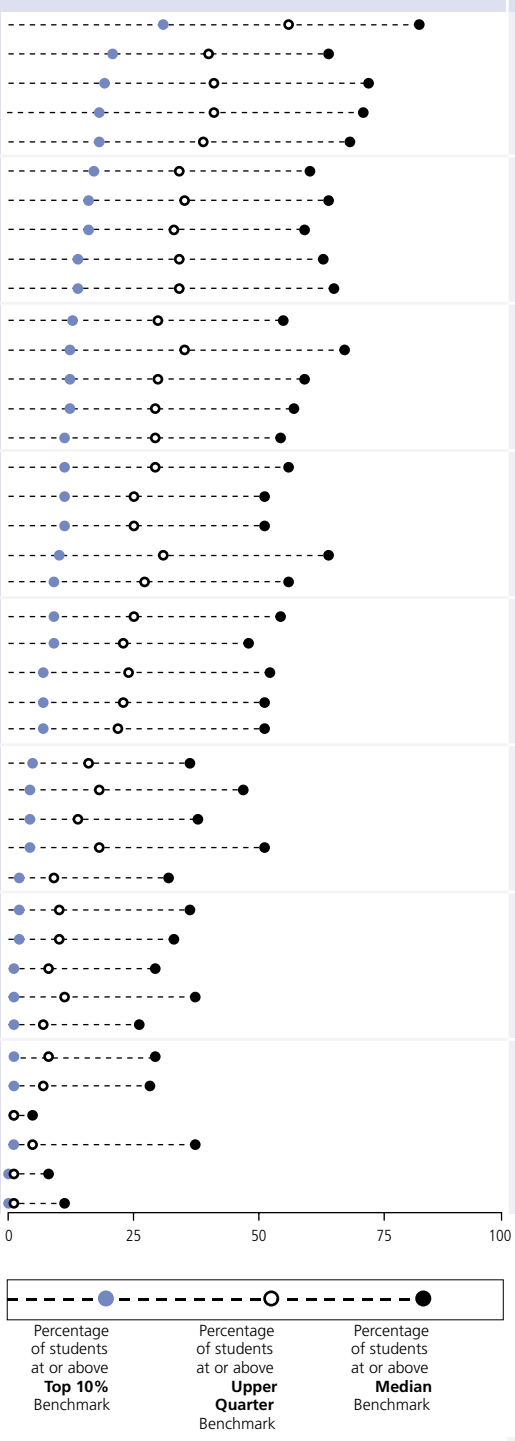
Recognize elementary facts presented in everyday language and context about earth's physical features and the solar system, human biology, plant and animal characteristics, life cycles; recognize facts about a range of familiar physical phenomena — rainbows, magnets, soap bubbles, boiling, cooling, floating, dissolving; begin to reason from everyday experience or observation; interpret labeled pictures and simple diagrams.

FIGURE 1

FIGURE 2

Percentages of Students Reaching TIMSS International Benchmarks of Science Achievement — Eighth Grade*

	Top 10%	Upper Quarter	Median	Lower Quarter
Singapore	31 (2.3)	56 (2.5)	82 (1.6)	95 (0.5)
Bulgaria	21 (1.4)	40 (2.2)	64 (2.3)	85 (1.3)
Czech Republic	19 (1.6)	41 (2.1)	72 (1.6)	92 (0.8)
Japan	18 (0.6)	41 (0.8)	71 (0.7)	91 (0.4)
Korea, Rep. of	18 (0.8)	39 (0.9)	68 (0.9)	89 (0.6)
England	17 (0.9)	34 (1.4)	60 (1.4)	83 (1.1)
Austria	16 (0.9)	35 (1.2)	64 (1.6)	87 (1.3)
Australia	16 (0.9)	33 (1.3)	59 (1.6)	81 (1.1)
Hungary	14 (0.8)	34 (1.3)	63 (1.4)	88 (0.9)
Slovenia	14 (0.9)	34 (1.3)	65 (1.2)	89 (0.7)
United States	13 (0.8)	30 (1.6)	55 (1.9)	79 (1.6)
Netherlands	12 (1.1)	35 (2.3)	67 (2.4)	90 (1.8)
Slovak Republic	12 (0.9)	30 (1.4)	59 (1.5)	85 (1.0)
Ireland	12 (0.9)	29 (1.6)	57 (2.0)	82 (1.7)
Germany	11 (1.0)	29 (1.6)	54 (2.1)	79 (1.7)
Russian Federation	11 (0.8)	29 (1.3)	56 (1.8)	83 (1.5)
Israel	11 (1.2)	25 (2.3)	51 (2.6)	77 (2.0)
New Zealand	11 (0.9)	26 (1.5)	51 (1.9)	77 (1.5)
Belgium (Flemish)	10 (0.8)	31 (1.8)	64 (2.1)	88 (1.6)
Sweden	9 (0.6)	27 (1.2)	56 (1.5)	83 (1.0)
Canada	9 (0.6)	25 (0.9)	54 (1.3)	81 (1.0)
Scotland	9 (1.1)	23 (1.8)	48 (2.2)	75 (1.5)
Norway	7 (0.5)	24 (0.9)	52 (1.1)	82 (0.8)
Switzerland	7 (0.6)	23 (1.0)	51 (1.2)	77 (1.1)
Hong Kong, SAR	7 (0.8)	22 (1.5)	51 (2.3)	79 (1.8)
Romania	5 (0.6)	16 (1.3)	36 (2.0)	62 (1.9)
Spain	4 (0.3)	18 (0.7)	47 (1.0)	81 (0.7)
Greece	4 (0.4)	14 (0.7)	38 (1.3)	68 (1.2)
Thailand	4 (0.5)	18 (1.7)	51 (2.2)	86 (1.1)
Denmark	2 (0.3)	9 (0.7)	32 (1.3)	61 (1.5)
Iceland	2 (0.5)	10 (1.3)	36 (2.1)	69 (2.3)
Latvia (LSS)	2 (0.3)	10 (0.7)	33 (1.3)	66 (1.4)
Lithuania	1 (0.3)	8 (0.8)	29 (1.7)	61 (1.9)
France	1 (0.2)	11 (0.8)	37 (1.5)	73 (1.3)
Cyprus	1 (0.2)	7 (0.5)	26 (0.9)	55 (1.1)
Belgium (Fr)	1 (0.2)	8 (0.6)	29 (1.4)	59 (1.7)
Portugal	1 (0.1)	7 (0.6)	28 (1.2)	63 (1.3)
South Africa	1 (0.2)	1 (0.3)	5 (1.3)	11 (2.2)
Iran, Islamic Rep.	1 (0.1)	5 (0.6)	24 (1.5)	58 (1.3)
Colombia	0 (0.1)	1 (0.2)	8 (0.9)	30 (1.7)
Kuwait	0 (0.0)	2 (0.3)	11 (1.2)	37 (2.1)



Top 10% Benchmark (90th Percentile) = 655

Upper Quarter Benchmark (75th Percentile) = 592

Median Benchmark (50th Percentile) = 522

Lower Quarter Benchmark (25th Percentile) = 451

*Eighth grade in most countries.

( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.

The international benchmarks correspond to the percentiles computed from the combined data from all of the countries participating in 1995.

SOURCE: IEA Third International Mathematics and Science Study (TIMSS), 1994-1995.

FIGURE 2

Summary of Performance at TIMSS International Benchmarks
Science — Eighth Grade

Top 10% International Benchmark

Apply knowledge of the formation of earth's features, the water cycle, and photosynthesis; identify the most abundant gas in air, recognize the basic structure of the atom and that living tissue is made up of atoms and molecules; distinguish between chemical and physical changes; demonstrate understanding of abstract physics concepts, including the effect of light reflection and absorption on the appearance of color, energy efficiency, and constant temperature during phase change; using diagrams, apply basic physical principles to develop explanations and make connections; understand the fundamentals of scientific investigation.

Upper Quarter International Benchmark

Demonstrate awareness of current environmental issues and basic knowledge about rocks and soil; recognize that plants need minerals and light; understand that burning is a chemical reaction that releases energy; demonstrate beginning knowledge of energy conversions and the structure and chemical properties of matter; apply basic knowledge about light, gravity, and forces to everyday situations; interpret force and ray diagrams; combine sources of information to draw conclusions and provide brief explanations; understand some aspects of scientific investigation.

Median International Benchmark

Demonstrate some knowledge of the development and use of earth's natural resources; recognize facts and terminology related to the characteristics of major animal groups, the interdependence among living things, and basic attributes of cells; identify basic properties of light and radiation; apply knowledge of circular motion and thermal expansion; interpret representational diagrams; provide brief descriptive explanations conveying practical knowledge.

Lower Quarter International Benchmark

Recognize some basic facts from the earth, life, and physical sciences presented using non-technical language, including the earth's physical features and solar system, the function of nerves and the brain, the inheritance of traits, characteristics of plants and animals, physical properties of materials, and the need for oxygen in rusting and burning; demonstrate beginning knowledge of mirrors and light reflection; interpret and use information presented in labeled pictorial diagrams, tables, and graphs; provide short written responses containing a single piece of factual information.

FIGURE 2

Comparing TIMSS Benchmarks with the National Science Education Standards

In the last decade, a great deal of work has been done in the United States at the national, state, and local levels to reform science education and establish clear and high standards for performance. Following the 1989 endorsement of the National Education Goals by the National Governors' Association, national organizations of science educators developed science education standards aimed at increasing the science literacy of all students. The two most prominent documents are the American Association for the Advancement of Science (AAAS) *Benchmarks for Science Literacy*[4] and the National Research Council's *National Science Education Standards* (NSES).[5] *Benchmarks for Science Literacy* recommends how students should progress toward science literacy and what they should know and be able to do by the time they reach certain grades. *National Science Education Standards* contains a vision for science education in the areas of teaching, professional development, assessment, content, education programs, and education systems. Both documents define standards for the learning and teaching of science that state and local educational systems may use to fashion their own science curricula. The National Science Teachers Association (NSTA) has published a series of practical guidebooks for science teachers to help implement the National Science Education Standards.[6]

The TIMSS test was administered in 1995, around the time of the publication of the *National Science Education Standards*; thus, science curriculum frameworks based specifically on the NSES were developed after the TIMSS test was administered. Despite this, the NSES document was chosen as the basis for comparison with performance on TIMSS since it is the most recent set of standards put forth at the national level. Moreover, the NSES represents the culmination of efforts over the past decade to define science education standards in the United States.

The science content standards presented in the NSES document describe a set of outcomes for students. They are divided into eight categories: unifying concepts and processes in science; science as inquiry; physical science; life science; earth and space science; science and technology; science in personal and social perspectives; and history and nature of science. The standards are grouped according to grade bands K–4, 5–8, and 9–12. Within each grade band a set of "expectations" are given that describe the understandings students should develop by that grade level.

4 | American Association for the Advancement of Science (1993).

5 | National Research Council (1995).

6 | National Science Teachers Association (1997a; 1997b; 1998).

It is assumed that the understandings attained in lower grades will be carried through to the higher grades so that scientific knowledge and understanding builds across grades.

The earth and space science content standards for grades K–4 specify that students should develop an understanding of the properties of earth materials, objects in the sky, and changes in earth and sky. At these grades, the standards focus on students' ability to observe and describe the world around them. For grades 5–8, the NSES specify that students should develop an understanding of the structure of the earth system, earth's history, and earth in the solar system. The goal is for "students to develop an understanding of earth and the solar system as a set of closely coupled systems….that provide a framework in which students can investigate the four major interacting components of the earth system — geosphere, hydrosphere, atmosphere, and biosphere."

The NSES life science standards state that as a result of activities in grades K–4, all students should develop understanding of the characteristics of organisms; life cycles of organisms; and organisms and their environments. At grades 5–8, students should develop an understanding of structure and function in living systems; reproduction and heredity; regulation and behavior; populations and ecosystems; and diversity and adaptations of organisms. The standards state that "students should progress from studying life science from the point of view of individual organisms to recognizing patterns in ecosystems and developing understandings about the cellular dimensions of living systems."

The fundamental concepts and principles that underlie the NSES physical science standards at grades K–4 incorporate three broad areas: properties of objects and materials; position and motion of objects; and light, heat, electricity, and magnetism. These areas are expanded for grades 5–8 to include properties and changes of properties in matter; motions and forces; and transfer of energy. The properties of objects and materials are addressed across grades. In the lower grades, the properties are observable: such as size, shape and color. At the grade 5–8 level, more abstract concepts are introduced, such as density. At the higher grades atomic structure in considered.

To analyze U.S. achievement in light of current priorities for science instruction and students' learning, U.S. performance at the four TIMSS international benchmarks for fourth and eighth grades was compared with expectations articulated in the *National Science Education Standards*. Three of the science educators from

the United States — Audrey Champagne, Christine O'Sullivan and Senta Raizen — who had served on the panel that developed the TIMSS international benchmarks, worked through the *National Science Education Standards* document and gauged how performance at the TIMSS international benchmarks is reflected in the NSES content standards. For each TIMSS item, the panel determined the content standard and the fundamental ability and concept underlying the standard with which it aligned. When doing so, the panel considered what students needed to know or be able to do to answer the question or problem correctly and the benchmark to which the item belonged (that is, at which benchmark students were likely to answer the item correctly). With all of the TIMSS items matched with the NSES content standards and expectations, the panel evaluated the overall match between the TIMSS tests and the *National Science Education Standards*.

The comparison shows that in many content areas there is a solid overlap between the content standards in the NSES document and performance on TIMSS. This is particularly true in some of the life science and earth science areas. In fact, some of the understandings specified in the NSES go beyond those reflected in the TIMSS tests. For example, in earth science, the standards include concepts such as the properties of soil and what fossils tell us about the past. The life science standards call for students to differentiate between inherited and learned traits. These topics are not included in the TIMSS tests. In the physical sciences, however, some understandings required on the TIMSS test are not reflected in the NSES content standards, particularly at the eighth grade. In some areas, TIMSS items fit within the broad content areas specified in the content standard. However, the specific knowledge and skills required by the items do not fit any of the more specific fundamental concepts and principles underlying the standard that are described in the "guide to the content standard."

For the most part, the content of the TIMSS fourth-grade test matched the NSES content standards for grades K–4, and that of the TIMSS eighth-grade test matched the content standards for grades 5–8. Nearly all of the TIMSS fourth-grade items aligned with one or more of the K–4 content standards, although the knowledge and skills required for some items are only indirectly addressed in the standards. Some fourth-grade items, while they fit within the general content standards, go beyond the expectations set forth in the NSES document for grades K–4. In fact, a few items included in the TIMSS fourth-grade test are more closely aligned with the grade 5–8 standards.

The eighth-grade TIMSS items also had a good overall match with the NSES content standards, with most items aligning with the expectations for grades 5–8. Some items, particularly in the life sciences, were aligned with K–4 expectations. The understandings of physical science required for some eighth-grade TIMSS items go beyond the NSES expectations for grades 5–8 and, in some cases, are not included in the standards until the grade 9–12 level.

In the next two sections of the report, achievement at the TIMSS international benchmarks for fourth and eighth grades is discussed in more detail and example items are presented to illustrate performance. The overlap between the content standards articulated in the NSES document and performance on TIMSS is also addressed.

Fourth Grade

International Benchmarks of Science Achievement

Fourth Grade

Fourth Grade

International
Benchmarks of Science Achievement — Fourth Grade

This section describes student performance at each of the four TIMSS international benchmarks for fourth grade and shows examples from the sets of items used to describe performance at each benchmark. For each benchmark, a number of items are presented to illustrate performance. Within each benchmark discussion of performance and the example items are grouped by content area — earth science, life science, and physical science. These are items that students reaching each benchmark were likely to answer correctly and they represent the kinds of items on which these students typically are successful. For each item, the percent correct for the United States and the highest-performing country are shown, as is the international average percent correct. Because some items will be used in future TIMSS assessments, not all of the items used to develop descriptions of performance are available for display. However, brief descriptions of every item used to develop the benchmark descriptions are provided in the appendix.

FIGURE 3 Grade 4

Top 10% International Benchmark — Fourth Grade

Demonstrate beginning knowledge of plant and animal development, reproduction and heredity; know some basic information related to human physiology; demonstrate beginning knowledge of light properties and energy sources; apply scientific understanding to interpret maps, diagrams and data tables; recognize aspects of scientific investigation; provide written responses requiring two or more pieces of information.

Students reaching the Top 10% benchmark apply knowledge of earth features to interpret a map indicating that a river flows from mountains to the ocean and interpret data in a table of temperature and precipitation to identify a location where it snowed. Students can describe at least two ways to reduce air pollution and give two reasons why oil spills in rivers and seas harm the environment.

Students at this level demonstrate beginning knowledge of plant and animal development. For example, they recognize that unhatched chicks live on food stored in the egg. They identify lack of air as the reason seeds covered with water do not grow. Students recognize that offspring are not produced by pollination of a flower by a tree and that a person's adult height is affected by the height of their parents. They can identify the normal human body temperature and explain why we get thirsty on a hot day. They can describe two physical changes that occur during human growth and development.

Students demonstrate beginning knowledge of the properties of light. They distinguish between an object that produces light (a candle) and objects that reflect, transmit, or focus light. They recognize that the light travels faster than sound, airplanes or trains and can determine the apparent position of a reflected image in a three-dimensional representation. Students recognize the sun, oil, and flowing water as sources of energy and identify lack of pollution as an advantage of solar energy. They also recognize how to position two children of unequal weight to balance a seesaw.

Students demonstrate rudimentary knowledge about some aspects of scientific investigation. They recognize the importance of measurement and can identify that a well-designed investigation of whether seeds grow better in light or dark requires two groups of seeds (one for the light and one for the dark).

Fourth-Grade Achievement at the Top 10% International Benchmark

Figure 3 presents the descriptions of performance at the Top 10% international benchmark for fourth grade. Students reaching this benchmark have demonstrated nearly full mastery of the content of the TIMSS fourth-grade science test. They typically demonstrate success on the knowledge and skills represented by this benchmark, as well as those defining performance at the Upper Quarter, Median, and Lower Quarter benchmarks. In the United States, 16 percent of fourth-grade students scored at or above the Top 10% international benchmark, 6 percent above the international percentage.

Earth Science

Most of the TIMSS earth science items related to the earth's features, resources, and solar system were answered successfully by students performing below the Top 10% benchmark. It is at the Top 10% benchmark, however, that students demonstrate that they can apply their knowledge of earth's materials to interpret and use information in diagrams and tables.

Example item 1 requires knowledge of the freezing point of water. It also requires the ability to interpret information in a fairly complex temperature/precipitation data table and draw a conclusion about the location where snow occurred. Students had to identify the location where there was precipitation and where the temperature was below the freezing point.

Internationally, 44 percent of fourth-grade students answered the item correctly. U.S. performance (54 percent correct) was higher than the international average. In top-performing Japan, 69 percent selected the correct answer.

Grade 4 Example 1

Applies knowledge about weather and freezing point of water to interpret and draw conclusions from data in a temperature/precipitation table.

This table shows the temperature and precipitation (rain or snow) in four different towns on the same day.

	Town A	Town B	Town C	Town D
Lowest Temperature	13˚C	-9˚C	22˚C	-12˚C
Highest Temperature	25˚C	-1˚C	30˚C	-4˚C
Precipitation (rain or snow)	0 cm	5 cm	2.5 cm	0 cm

Where did it snow?

A. Town A
B. Town B
C. Town C
D. Town D

In the United States, the table presented to students showed temperatures in °F.

N01

Percent Correct

★ United States 54

▲ Japan 69

● International Avg. 44

This item can be mapped to the NSES earth and space science standard related to changes in the earth and sky which calls for K–4 students to understand the following concepts: "Weather changes from day to day and over the seasons," and "Weather can be described by measurable quantities such as temperature, wind direction and speed, and precipitation." This item also can be mapped to the NSES physical science standard that relates to the properties of objects: "Materials can exist in different states — solid, liquid and gas. Some common materials, such as water, can be changed from one state to another by heating and cooling."

Life Science

While students at the lower TIMSS benchmarks demonstrate knowledge of basic facts related to the characteristics and life cycles of animals and plants, at the Top 10% benchmark students also demonstrate beginning knowledge of reproduction, heredity, and development. Example items 2 and 3 illustrate this knowledge.

In example item 2, 43 percent of fourth graders internationally recognized that a developing chick uses food that is stored in the egg before it hatches. About the same percentage of fourth-grade students in the U.S. (44 percent) responded correctly, compared with 72 percent in the highest-performing country, Korea.

Example 2 Grade 4

Recognizes that unhatched chicks consume food source that is stored in the egg.

A baby chick grows inside an egg for 21 days before it hatches. Where does the baby chick get its food before it hatches?

A. It is fed by the mother hen.

B. It doesn't need any food.

C. It makes its own food.

(D.) It uses food stored in the egg.

E. It eats the egg shell.

N06

Percent Correct

★ United States
44

▲ Korea
72

● International Avg.
43

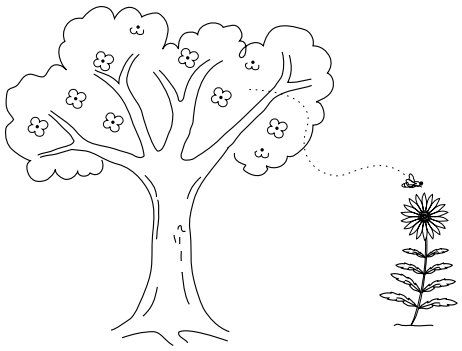
In example item 3, 55 percent of fourth-grade students internationally recognized that pollen carried from a flower on a tree to a flower on a plant would not result in offspring. The performance in the U.S. (60 percent correct) was above the international average, but well below the Czech Republic and Slovenia (79 percent correct).

The concepts understood by students at the Top 10% benchmark are included in the NSES content standard related to life cycles of organisms. The content standards state that by the fourth grade students should develop an understanding that "plants and animals have life cycles that include being born, developing into adults, reproducing, and eventually dying," that "plants and animals closely resemble their parents," and that "many characteristics of an organism are inherited from the parents of the organism."

Grade 4 Example 3

Demonstrates knowledge of plant reproduction by recognizing that offspring are not produced from mixing pollen of incompatible plant species.

The picture shows how an insect can carry pollen from the flowers of a tree to the flowers of a small plant.



What will most likely happen?

A. The offspring from the tree will look like the plant.

B. The offspring from the plant will look like the tree.

C. The offspring from the plant will look like the tree and the plant.

(D.) Nothing will happen because no offspring will be produced.

R03

Percent Correct

★ United States
60

▲ Czech Republic
79

▲ Slovenia
79

● International Avg.
55

Example 4 Grade 4

Demonstrates knowledge of the relationship between perspiration and dehydration by describing the reason for thirst on a hot day.

Write down the reason why we get thirsty on a hot day and have to drink a lot.

It is because we are sweating.

W03

Percent Correct

★ United States
29

▲ Slovenia
44

▲ Singapore
43

● International Avg.
27

At the Top 10% benchmark, students demonstrate emerging knowledge of human bodily processes beyond that demonstrated by students at lower benchmarks. Example item 4 requires students to give the reason for thirst on a hot day by relating thirst and the need for water with perspiration. This item was quite difficult for fourth-grade students, with only slightly more than a quarter of fourth-grade students internationally describing the correct reason, and fewer than half in the two top-performing countries doing so. U.S. fourth graders performed similar to the international average, with 29 percent correct.

This item also was administered to eighth graders. It was an item that eighth-grade students reaching the Median benchmark were likely to answer correctly. The concepts and principles relating to regulation and behavior is not expected of students by the NSES until middle school.

Providing written responses requiring two or more pieces of information is a hallmark of the Top 10% benchmark. Several items on the TIMSS fourth-grade test asked students to give "two reasons" or "two examples" based on their scientific knowledge of life science or environmental science. While students at the Median benchmark could provide a single response for those types of items, it was at the Top 10% benchmark that students were able to answer fully, giving two reasons or examples. Example item 5 is a life science item which most students reaching the Top 10% benchmark could answer fully. In this item, students provided two or more examples of the physical changes in children's bodies as they become adults. At the Median benchmark students could describe one physical change, mostly related to growth, such as increases in height or weight. Overall, 34 percent of fourth-grade students internationally described two physical changes, compared with 45 percent in the U.S. and 58 percent in Korea.

Example 5 Grade 4

Communicates two or more examples of physical changes because of human growth and development.

Write down two changes that occur in children's bodies as they become adults.

They grow taller and they grow beards.

Y02

Percent Correct

★ United States
45

▲ Korea
58

● International Avg.
34

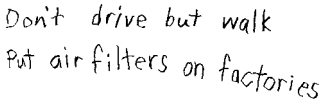
Although the majority of students at the Median benchmark could write down one example of things people can do to help reduce air pollution (example item 6), most students at the Top 10% benchmark could give two examples. Internationally, 27 percent of fourth-grade students overall provided two examples. In the United States, 40 percent of fourth graders were able to do so, compared to 46 percent in the Netherlands.

The concepts and principles required to answer both example items 5 and 6 are found in the NSES life science standards calling for students to understand that "Plants and animals have life cycles that include being born, developing into adults, reproducing and eventually dying" and that "Humans change environments in ways that can be either beneficial or detrimental for themselves and other organisms."

Grade 4 Example 6

Communicates two or more examples of how people can help reduce air pollution.

Write down two different things that people can do to help reduce air pollution.



W05

Percent Correct

★ **United States** 40

▲ **Netherlands** 46

● **International Avg.** 27

Physical Science

While students at the lower benchmarks demonstrate knowledge of a number of physical concepts, basic knowledge of balanced forces and some properties of light is not evidenced until the Top 10% benchmark. In example item 7, students were asked to apply practical knowledge of or experience with levers and balanced forces. The majority of students at the Top 10% benchmark identified the correct positions required for two people of different weights to balance a seesaw. Less than half of the fourth-grade students overall in the U.S. (44 percent) and internationally (46 percent) were able to do this. This performance was substantially below the top-performing country, Korea, where 84 percent of fourth-graders responded correctly.

The concept of balanced forces is indirectly addressed in the NSES K–4 standards. However, specific standards about this are not included until the grades 5–8 standards.

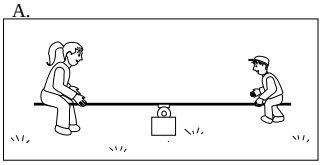
Example 7 Grade 4

Identifies the diagram that shows how to balance two people of unequal weight on a seesaw.

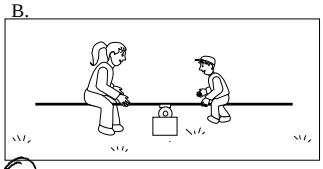
A girl wanted to play on a seesaw with her little brother.

Which picture shows the best way for the girl, who weighed 50 kg (kilograms), to balance her brother, who weighed 25 kg?

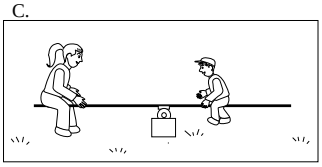
A.



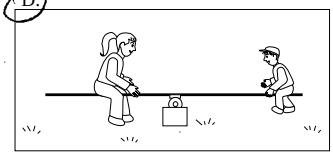
B.



C.



D.



O01

Percent Correct

★ United States
44

▲ Korea
84

● International Avg.
46

Students reaching the Top 10% benchmark demonstrated a beginning knowledge of the properties of light. In example item 8, a little more than half of fourth-grade students internationally (52 percent) and in the U.S. (55 percent) were able to distinguish between a light source (candle flame) and objects that reflect, transmit, or focus light. In top-performing Austria, 83 percent of students answered the item correctly.

Example item 9 required students to draw the apparent position of a reflected image in a three-dimensional diagram. Less than half of the fourth-grade students in the U.S. and internationally were able to indicate both the correct distance from the mirror plane and the orientation of the pencil. In comparison, 66 percent of fourth-grade students in Singapore could do so. While the NSES physical science content standard indicates that students should understand that "light can be reflected by a mirror," the ability to draw the apparent reflected image is beyond the general standard related to light reflection.

Grade 4 Example 8

Distinguishes between a light source and objects that reflect, transmit or focus light.

Which makes its own light?

A. A mirror

B. A candle flame

C. A diamond ring

D. A magnifying lens

R08

Percent Correct

★ United States
55

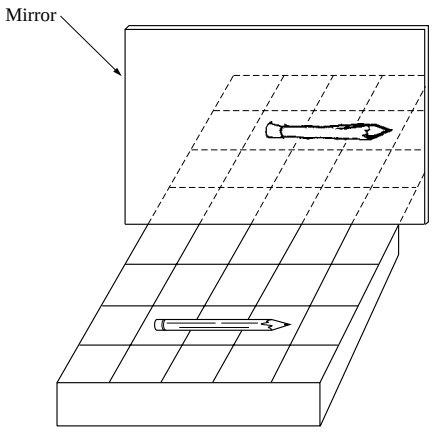
▲ Austria
83

● International Avg.
52

Grade 4 Example 9

Draws the apparent position of a reflected image in a mirror on a diagram representing three dimensions.

The picture shows a pencil that is lying on a shelf in front of a mirror. Draw a picture of the pencil as you would see it in the mirror. Use the patterns of lines on the shelf to help you.



Q08

Percent Correct

★ United States
43

▲ Singapore
66

● International Avg.
47

At the Top 10% benchmark, students could distinguish energy sources in a list of sources and non-sources. They also identify lack of pollution as an advantage of solar energy. In example item 10, less than half of fourth-grade students internationally (44 percent) and in the U.S. (47 percent) recognized an advantage of solar energy. In Japan, however, 80 percent of fourth-grade students selected the correct response. Concepts of energy are not formally introduced in the NSES until the grade 5–8 level.

Example 10 Grade 4

Recalls and applies information about energy sources to recognize advantages of solar energy.

One advantage of solar energy is that it

A. does not pollute

B. is not renewable

C. is efficient in any climate

D. is available at all times

R09

Percent Correct

★ United States
47

▲ Japan
80

● International Avg.
44

Scientific Investigation

At the Top 10% benchmark students demonstrated knowledge of aspects of scientific investigation by recognizing some features of well-designed investigations. For example, they recognized what constitutes a fair test, identified what data needed to be collected, and could draw conclusions based on given results.

In example item 11, students need to realize that two groups of seeds — one placed in the dark and one in the light — is a requirement of a well-designed investigation on the effect of light on plant seed development. Internationally, 36 percent of fourth-grade students knew this. With 61 percent correct, the U.S. fourth-graders performed well above the international average on this question, and very close to top-performing Korea (66 percent). U.S. performance on this item was consistent with the emphasis placed on scientific inquiry in the NSES grades K–4 Science as Inquiry content standard, which calls for students to develop abilities and understandings about scientific inquiry. These include asking questions that can be answered by their own observations and investigations, planning and conducting a simple investigation, using equipment to gather data, and using data to construct a reasonable explanation.

Grade 4 Example 11

Recognizes the conditions required for a well-designed investigation, given a definition of the problem.

To find out whether seeds grow better in the light or dark, you could put some seeds on pieces of damp paper and

A. keep them in a warm, dark place

B. keep one group in a light place and another in a dark place

C. keep them in a warm, light place

D. put them in a light or dark place that is cool

P06

Percent Correct

★ United States
61

▲ Korea
66

● International Avg.
36

FIGURE 4 Grade 4

Upper Quarter International Benchmark — Fourth Grade

Demonstrate some understanding of earth processes and resources; demonstrate some knowledge of structure and function in plants and animals; recognize some basic terminology and chemical and physical properties of familiar materials; apply knowledge to practical situations; provide brief descriptions and explanations of everyday phenomena.

Students reaching the Upper Quarter benchmark demonstrate some understanding of earth processes and resources. They recognize that metals are found in rocks, distinguish between renewable and non-renewable energy sources, and recognize that river flooding is not entirely predictable. They can explain why mountains can still have snow on their tops when snow on lower parts has melted.

Students demonstrate some knowledge of structure and function in plant and animal biology. They recognize that seeds develop from the flowers of a plant. They describe one function of the human heart, and one advantage of the human skull being thick and strong.

In the physical sciences, students demonstrate beginning knowledge of chemical and physical properties of matter. For example, they recognize that plastic will decay more slowly than paper, orange peel, or egg shell, and that a powder made up of both black and white specks is likely to be a mixture. Students know that a magnet can be used to separate a mixture of iron filings and sand, and can interpret a diagram to identify a non-magnetic substance based on the absence of magnetic attraction. They can interpret a diagram to identify the angle of a beam of light reflected from a mirror and recognize that food is the source of energy for human activity. Students can explain why soup stays hot longer in a covered bowl and why loose sugar dissolves faster than cubes. From a diagram comparing masses on a scale, they can determine the heaviest of three objects and explain their answer.

Students at this level demonstrate emerging scientific inquiry skills by recognizing statements that are observations.

Students at this level are able not only to select a correct response but also to provide a brief explanation justifying their reasoning (e.g., how to determine the heaviest weight using scales, why soup stays hotter in a covered bowl, why loose sugar dissolves faster than cubes). They also provide brief descriptive responses combining knowledge of science concepts with information from everyday experience of physical and life processes (e.g., why there is more snow on mountain tops, circulatory function of the heart, advantage of thick and strong skull).

Fourth-Grade Achievement at the Upper Quarter International Benchmark

Figure 4 describes performance at the Upper Quarter international benchmark for fourth grade. Students reaching this benchmark typically demonstrate the knowledge and skills represented by this benchmark, as well as those defining performance at the Median and Lower Quarter benchmarks. In the United States, 35 percent of fourth-grade students scored at or above the Upper Quarter international benchmark, 10 percent higher than the international percentage.

Earth Science

While students at lower benchmarks demonstrate some knowledge of the use of soil and water, those at the Upper Quarter benchmark demonstrate additional knowledge of earth's natural resources, recognizing, for example, that metals are found in rocks, and distinguishing between renewable and nonrenewable energy sources.[1] Knowledge in both of these areas is covered in the general language of the NSES document but is not explicitly stated in the concepts and principles underlying the standards. The standard related to properties of earth materials states that "The varied materials have different physical and chemical properties, which make them useful in different ways…" The "Science in Personal and Social Perspectives" standard states that students should develop an understanding of types of resources. The guide to this standard specifies the concept of limited resources but does not explicitly include the ability to distinguish between renewable and nonrenewable energy sources.

1 All items related to these concepts, and typical of performance at this benchmark, are secure items and therefore cannot be published in this report.

Example 12 Grade 4

Applies and communicates knowledge of principles of precipitation/ temperature as a function of elevation to explain why there is more snow on mountain tops.

Sometimes mountains can still have snow on their tops when the snow on the lower parts of the mountains has melted. What makes this happen?

Because the lower part is warmer.

O09

Percent Correct

★ United States
53

▲ Japan
73

▲ Korea
70

● International Avg.
46

Example 13 Grade 4

Recognizes the flower as the part of the plant from which seeds develop.

Seeds develop from which part of a plant?

(A.) Flower
B. Leaf
C. Root
D. Stem

P09

Percent Correct

★ United States
37

▲ Czech Republic
79

● International Avg.
46

Students at the Upper Quarter benchmark also demonstrate familiarity with some of the changes in earth's conditions, such as the unpredictability of flooding and changes in weather at different altitudes. In example item 12, students describe why there can be snow on the top of a mountain when the snow at lower altitudes has melted. Nearly half of fourth-grade students internationally (46 percent) gave a correct response referencing either the colder temperature or a greater amount of snowfall at higher altitudes. The United States performed above the international average, with 53 percent correct, but not as well as top-performing Japan (73 percent) and Korea (70 percent).

Knowledge about changes in weather as a function of elevation would not be expected of fourth-grade students by NSES; the earth science standard related to weather changes contains guidelines related only to the basic knowledge that weather changes over time and can be described by measurable quantities.

Life Science

At the Upper Quarter benchmark, students begin to demonstrate knowledge of structure and function in plants and animals. The NSES life science content standard related to this topic specifies that students should understand that "each plant or animal has different structures that serve different functions in growth, survival, and reproduction"; more specific standards about structure and function in living systems are not included until grades 5–8.

Both example items 13 and 14 are aligned with this general content standard. In example item 13, students identify the flower as the plant part from which seeds develop. Internationally, 46 percent of fourth-grade students answered this correctly. Substantially less than half of fourth-graders in the U.S. (37 percent) responded correctly, compared with 79 percent in the Czech Republic.

Knowledge of the function of the human heart was demonstrated by 40 percent of fourth-grade students internationally in example item 14. The U.S. was one of the highest-performing countries on this item (64 percent), topped only by Australia (69 percent).

Grade 4 Example 14

Communicates knowledge by describing that the heart circulates blood through the body.

Write down one thing your heart does that helps the other parts of your body.

Your heart pumps blood to all parts of your body.

W02

Percent Correct

★ United States 64

▲ Australia 69

● International Avg. 40

Physical Science

At the Upper Quarter benchmark, students demonstrated beginning knowledge of physical and chemical properties of familiar materials and the classification of matter. In example item 15, students identified a heterogeneous powder as a mixture based on its physical description. In order to answer this item correctly, students had to be familiar with some scientific terminology (mixture, solution, compound, and element). Internationally, 61 percent of fourth-grade students identified the powder as a mixture, compared with 71 percent in the U.S. and more than 80 percent in the Netherlands and Korea.

Despite the high performance of U.S. students on example item 15, specific knowledge of the concept of a mixture and an understanding of the scientific terminology required is not expected in the NSES content standards until higher grade levels. The NSES grade K–4 physical science standards include the following general concepts: "Objects are made of one or more materials, such as paper, wood, and metal. Objects can be described by the properties of the materials from which they are made, and those properties can be used to separate or sort a group of objects or materials."

Grade 4 Example 15

From its physical description, identifies a heterogeneous powder as a mixture.

A powder made up of both white specks and black specks is likely to be

A. a solution

B. a pure compound

C. a mixture

D. an element

N08

Percent Correct

★ United States 71

▲ Netherlands 85

▲ Korea 83

● International Avg. 61

Example 16 Grade 4

Applies knowledge of magnetic properties by recognizing that a magnet can be used to separate a mixture of iron filings and sand.

In a box there is a mixture of iron filings and sand. Which is the easiest way to separate the iron filings from the sand?

A. Pour water on the mixture

B. Use a magnifying glass

C. Use a magnet

D. Heat the mixture

O08

Percent Correct

★ United States
53

▲ Korea
96

▲ Japan
89

● International Avg.
55

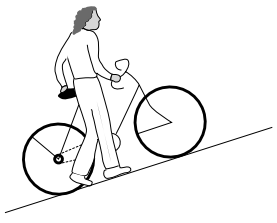
In example item 16, students applied knowledge of magnetic properties to a practical situation by recognizing that a magnet can be used to separate a mixture of iron filings and sand. Performance of U.S. fourth graders (53 percent) was close to the international average (55 percent). In contrast, nearly all of the students (almost 90 percent or more) in Korea and Japan selected the correct response. This item aligns with the NSES K–4 standard calling for students to understand that: "Magnets attract and repel each other and certain kinds of other materials."

The Upper Quarter benchmark is the lowest TIMSS benchmark at which the majority of students demonstrate some understanding of energy concepts. In example item 17, students apply basic knowledge of the concept of energy sources to identify food as the source of energy for human activity. Internationally, about half of fourth-grade students (52 percent) responded correctly. Performance by U.S. fourth graders was somewhat higher, with 60 percent answering the question correctly, compared with 70 percent in the Netherlands and Iceland. The general discussion in the grade K–4 physical science content standards states that students "have intuitive notions of energy — for example, 'energy is needed to get things done; humans get energy from food.'" More specific NSES content standards related to energy concepts are not included until the grade 5–8 level.

Example 17 Grade 4

Applies basic knowledge of energy sources to identify food as source of energy for human activity.

Keisha is pushing her bicycle up a hill. Where does Keisha get the energy to push her bicycle?



A. From the food she has eaten

B. From the exercise she did earlier

C. From the ground she is walking on

D. From the bicycle she is pushing

N07

Percent Correct

★ United States
60

▲ Netherlands
70

▲ Iceland
70

● International Avg.
52

Students at the Upper Quarter benchmark can give brief explanations justifying their scientific reasoning. Example items 18 and 19 illustrate the types of scientific explanations provided by fourth-grade students. On both items, about 40 percent of fourth-grade students internationally and in the U.S. provided a correct explanation. Only in Korea and Japan were most students (70 percent or more) able to do so.

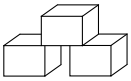
In example item 18, students explain why loose sugar will dissolve faster than sugar cubes. While students at the Lower Quarter benchmark correctly identified that loose sugar dissolves faster, students reaching the Upper Quarter level can support this answer with an explanation based on the compactness or relative size of the sugar particles. This item may be answered on the basis of prior observation and does not necessarily require conceptual understanding of the principles of solution.

The NSES physical science standards for grades K–4 emphasize the "study of matter by examining and qualitatively describing objects and their behavior." While the content standards expect students to be familiar with different states of matter (solid, liquid, and gas), they do not include concepts related to dissolving until higher grade levels.

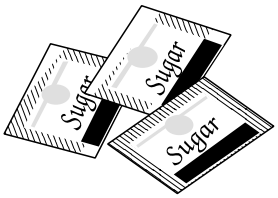
Grade 4 Example 18

Communicates knowledge of physical changes by explaining why loose sugar will dissolve faster than sugar cubes.

The picture shows two forms of sugar — solid cubes and packets of loose crystals. One cube has the same mass of sugar as one packet.



Sugar Cubes



Loose Sugar

Which of the two forms of sugar will dissolve faster in water? loose sugar
Give a reason for your answer.

The loose sugar is smaller so it will dissolve faster.

W01

Percent Correct

★ United States	43
▲ Korea	75
▲ Japan	72
● International Avg.	37

In example item 19, students explain their logic in determining the heaviest mass based on a diagram comparing masses on a scale. While the majority of students at the Median benchmark demonstrated familiarity with using scales to determine relative masses and identify the correct block, it is at the Upper Quarter level that students gave an adequate explanation supporting their conclusion.

The use of scales features in a number of content standards in NSES. In the physical science standards, weight is included in the observable properties of objects and materials that students are expected to be familiar with. In addition, it is stated that "those properties can be measured using tools, such as rulers, balances, and thermometers." Also, in the "Science as Inquiry" standard students are expected to "employ simple equipment and tools" including "scales to measure weight and force." The ability to explain the method used to determine the relative weights, however, goes beyond any of these standards.

Example 19 Grade 4

From a diagram comparing masses on a scale, reasons to a conclusion to determine the heaviest of three objects and explains answer.

The weights of three blocks were compared.

Which one of the three blocks weighs the most? (A, B, or C): C

Explain your answer.

B is heavier than A so if C can lift B that means C is heavier.

Z03

Percent Correct

★ United States
42

▲ Korea
74

▲ Japan
70

● International Avg.
37

Scientific Investigation

At the Upper Quarter benchmark students demonstrate emerging scientific inquiry skills. For example, in item 20, students evaluate statements made about an object and determine which are objective observations. In the U.S. and Korea, nearly 60 percent of fourth-grade students identified the statement that was not an observation, which is significantly above the international average of 43 percent.

The high performance in the U.S. is consistent with the emphasis the NSES places on the ability of K–4 students to make scientific observations of the world around them. The "Science as Inquiry" content standards also indicate that students should understand that "scientists develop explanations using observations (evidence)" and develop the ability to "answer their questions by seeking information from reliable sources of scientific information and from their own observations."

Grade 4 Example 20

Percent Correct

★ United States
58

▲ Korea
59

● International Avg.
43

Recognizes statements that are observations.

Four children can feel and smell an object inside a bag, but they cannot see it. Which of the following is NOT an observation about the object?

A. "It is flat at one end and round at the other."

B. "It smells like peppermint."

C. "It has a bump on it."

D. "I hope it is candy."

Q07

FIGURE 5 Grade 4

Median International Benchmark — Fourth Grade

Know some basic facts about earth's water, soil and pollution; recognize basic biological facts and terminology — attributes and habitats of common groups of animals, human life processes and health; demonstrate some understanding of physical concepts in practical contexts — burning, heat and temperature, weight (mass); interpret tabular and diagrammatic information; provide short factual written responses demonstrating practical knowledge.

Students reaching the Median benchmark know some basic facts about earth's water and soil. They recognize that most of earth's surface is covered by water and can give a reason why a wide plain with a river is a good place for farming. They also recognize the effect of rock hardness on abrasion. Students provide one example of how people can help reduce air pollution and one harmful effect of oil spills.

Students at this level demonstrate some knowledge of the diversity, structure and habitats of animal life. They match pictures of animals to descriptions of general physical characteristics using basic terminology (inside/outside skeleton, backbone, segments). They identify the habitats of some animal species (worms, web-footed birds), and can write one way that animals protect themselves from danger. Students at this level identify a feature that differentiates birds from insects and recognize that a spider is not an insect. They apply knowledge of fish characteristics to interpret information in a 2x2 classification table. They also can identify the order of the four developmental stages of a butterfly. Students recognize that exercise leads to increased breathing and pulse rate, that sensory messages are interpreted in the brain, and that excess food is stored as fat. They can write one change that occurs in children's bodies as they become adults and recognize that fruits and vegetables are rich in minerals and vitamins.

Students at this level know a few basic physical concepts. They recognize that heat causes the liquid in thermometers to expand and that kettles and pans are often made from copper because it is a good heat conductor. They explain that a lighted candle will go out when the flame is covered because of a lack of oxygen or air. Students recognize that a string telephone requires a tight string for sound transmission and are familiar with the use of scales to compare the weight (mass) of objects.

Students at this level apply factual knowledge to practical situations and demonstrate some ability to interpret information in pictorial diagrams to reason to a conclusion. For example, they interpret diagrams showing rock abrasion patterns to identify the hardest rock, identify the greatest/least mass from diagrams of weights on scales, and identify string tension condition for clear sound transmission from diagrams of string telephones. They provide short written responses to questions requiring single pieces of factual information (e.g., an example of pollution effects, a way animals protect themselves, a physical change that occurs during human growth/development, oxygen/air needed for burning, reason a plain with a river is good for farming).

Fourth-Grade Achievement at the Median International Benchmark

Figure 5 describes performance at the Median international benchmark for fourth grade. Students reaching this benchmark typically demonstrate the knowledge and skills represented by this benchmark, as well as the Lower Quarter benchmark. In the U.S., 63 percent of fourth-grade students scored at or above the Median international benchmark, 13 percent more than the international average.

Earth Science

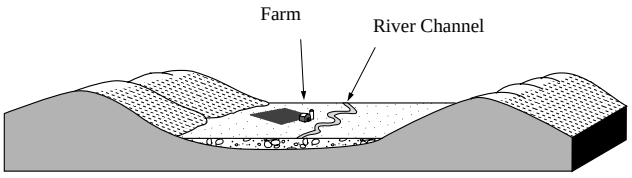
Knowledge of earth science and related topics at the Median benchmark includes the availability and use of soil and water. In example item 21, students at the Median benchmark can provide one reason why a plain with a river is a good place for farming. Sixty-two percent of fourth-grade students internationally and 83 percent in the U.S. gave a correct response to Part A, related to the availability of fertile soil or water for growing crops. Only Korea, with 91 percent correct, performed above the U.S. Part B of this item, requiring students to consider negative effects and provide a reason why the plain is NOT a good place for farming, such as flooding, was too difficult for most fourth-grade students, even those at the Top 10% benchmark.

This item aligns both with the NSES content standard for earth and space science related to properties and use of earth materials and with the life science standard related to organisms and their environments. These standards include understandings related to the dependence of humans on the environment and their use of earth's resources.

Grade 4 Example 21

Part A: Demonstrates knowledge of human use of soil and water resources by stating one reason a plain with a river is a good place for farming.

The diagram shows a river flowing through a wide plain. The plain is covered with several layers of soil and sediment.



a. Write down one reason why this plain is a good place for farming.

Because there is a river where the farmers could get fresh water.

b. Write down one reason why this plain is NOT a good place for farming.

The river could over flow during a rain storm.

Z01

Part A
Percent Correct

★ **United States** 83

▲ **Korea** 91

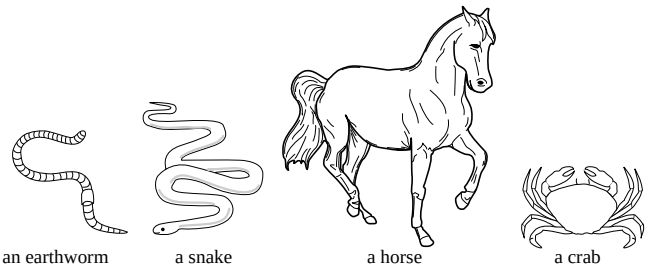
● **International Avg.** 62

Students at the Median benchmark also demonstrate some familiarity with common pollution effects by giving an example of how people can help reduce air pollution and a harmful effect of oil spills. The ability to give two examples was demonstrated by most students at the Top 10% Benchmark (see example item 6).

Example 22 Grade 4

Matches pictures of animals to descriptions of their physical characteristics using basic scientific terminology.

Use the pictures to answer the questions. (Use each animal once only.)



an earthworm a snake a horse a crab

An animal that has a hard outside skeleton is

Crab

An animal without a backbone that has many segments to its body is

Earthworm

An animal that has hair and an inside skeleton is

Horse

An animal that has a scaly skin and an inside skeleton is

Snake

Z02

Percent Correct

★ **United States** 78

▲ **Hong Kong** 94

● **International Avg.** 62

Life Science

Compared with their peers at the Lower Quarter benchmark, students at the Median benchmark demonstrated an increased knowledge of the diversity, structure, and habitats of animal life. Students at this level can recognize some basic characteristics of major groups of organisms and differentiate among organisms based on these characteristics. Several of the TIMSS items are based on the classification of organisms, and students in the U.S. performed at or above the international average on all of these items.

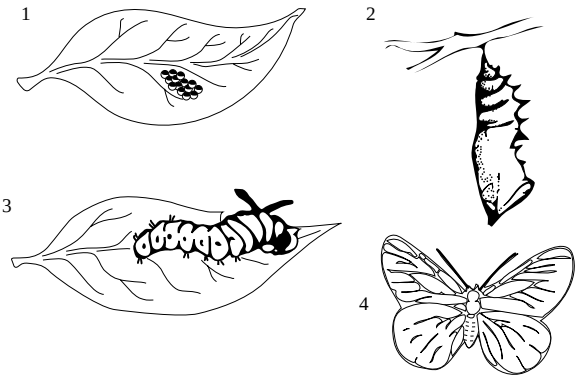
In example item 22, students match pictures of animals to descriptions of general physical characteristics using basic terminology (inside/outside skeleton, backbone, and segments). Internationally, 62 percent of students correctly identified all four animals. With 78 percent correct, the U.S. performed above the international average on this item, but still below Hong Kong (94 percent correct).

Classifying organisms is not specifically identified in the fundamental concepts and principles underlying the NSES life science content standards at the K–4 level. The standard entitled "Characteristics of Organisms" uses general language such as "each plant or animal has different structures that serve different functions in growth, survival, and reproduction;" it does not specify that by fourth grade students should be able to differentiate between organisms on the basis of these characteristics. However, the general discussion of developing student understanding does mention classification as a classroom activity.

Grade 4 Example 23

Identifies the order of the four developmental stages of a butterfly.

A butterfly sitting on a leaf laid some small eggs. The pictures show the changes that took place to the eggs.



In what order did the changes take place?

A. 1, 2, 3, 4

B. 1, 3, 2, 4

C. 1, 4, 3, 2

D. 1, 4, 2, 3

Q01

Percent Correct

★ United States 80

▲ Japan 92

● International Avg. 64

The NSES life science standards for grades K–4 emphasize the understanding of life cycles and indicate that students should know that "the details of life cycles are different for different organisms." While students at the Lower Quarter benchmark could identify life stages for some organisms, students at the Median benchmark exhibited more detailed knowledge. In example item 23 more than 60 percent of fourth graders internationally, 80 percent in the U.S. and over 90 percent in Japan identified the correct order of the four developmental stages of the butterfly.

Students at the Median benchmark also demonstrated some knowledge of human development. In example item 5 — presented for the Top 10% Benchmark — students at the Median benchmark correctly described *one* physical change that occurs as children become adults. The majority of students at the Median benchmark, however, could not provide a second physical change. While not explicitly stated in the NSES life science standards, human development falls within the general standards related to the life cycles of organisms, which includes "being born, developing into adults, reproducing, and eventually dying."

Example item 24 asks students to demonstrate knowledge of basic scientific terminology and human nutrition. More than 90 percent of students in the Netherlands and Austria recognized that fruits and vegetables were a source of minerals and vitamins. With 62 percent correct, the U.S. performed at about the international level (65 percent).

Only a very general reference to human nutrition is included in the NSES life science standards. These state that "Organisms have basic needs. For example, animals need air, water, and food." The "Science in Personal and Social Perspectives" content standard related to personal health indicates that "students should understand how the body uses food and how various foods contribute to health." The standards also indicate that students "understand connections between diet and health and that some foods are nutritionally better than others, but they do not necessarily know the reasons for these conclusions." Therefore, specific knowledge regarding the need for vitamins and minerals appears to go beyond the NSES expectations for fourth-grade students.

Example 24 Grade 4

Recognizes the nutritional value of fruits and vegetables as a source of vitamins and minerals.

What is the BEST reason for including fruits and leafy vegetables in a healthy diet?

A. They have a high water content.

B. They are the best source of protein.

C. They are rich in minerals and vitamins.

D. They are the best source of carbohydrates.

Q02

Percent Correct

★ United States
62

▲ Netherlands
93

▲ Austria
92

● International Avg.
65

Physical Science

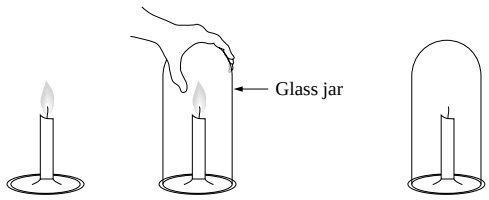
Students at the Median benchmark demonstrated knowledge of some physical concepts presented in practical contexts. In example item 25, students explain why covering a candle will extinguish the flame. More than 60 percent of fourth-grade students internationally and in the U.S., and 94 percent in Slovenia, explained that burning requires oxygen or air.

The NSES physical science standards do not cover this concept, and include only a general reference to objects having "the ability to react with other substances."

Grade 4 Example 25

Applies knowledge of the relationship between fire/burning and air/oxygen to explain why a covered flame goes out.

When a glass jar is placed over a lighted candle, the flame goes out.



Why does this happen?

It goes out because the air can't get in.

Q04

Percent Correct

★ United States
62

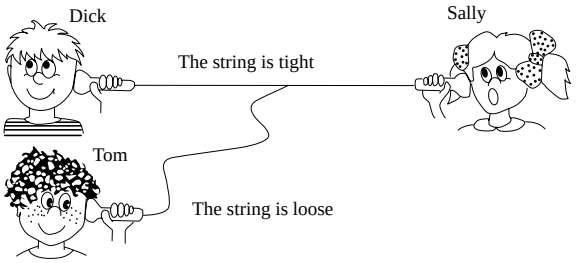
▲ Slovenia
94

● International Avg.
64

Example 26 Grade 4

Applies knowledge to a practical situation to interpret diagram of string telephone and identify condition of string tension required for clear sound transmission.

The picture shows Dick and his friends playing with a string-telephone. Sally is speaking. Dick and Tom are trying to listen. Which of them can hear her speak?



A. Both of them can hear equally clearly.

B. Neither of them can hear.

C. Only Tom can hear clearly.

D. Only Dick can hear clearly.

E. Both of them hear equally faintly.

R05

Percent Correct

★ **United States** 72

▲ **Japan** 86

▲ **Korea** 82

● **International Avg.** 58

In example item 26, students interpret a pictorial diagram of a string telephone and identify the taut string as a condition required for clear sound transmission. Internationally, 58 percent of fourth-grade students responded correctly to this item, with U.S. fourth graders performing above the international average (72 percent). More than 80 percent of students in Japan and Korea responded correctly.

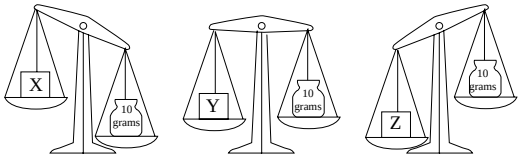
Development of concepts of sound are expected to progress across grades K–4 according to the NSES document. It states that "Sounds are not intuitively associated with the characteristics of their source by younger K–4 students, but that association can be developed by investigating a variety of concrete phenomena toward the end of the K–4 level." The standards also specify that students develop understanding that "Sound is produced by vibrating objects. The pitch of the sound can be varied by changing the rate of vibration." The level of knowledge required by this standard is well above that demonstrated in example item 26.

Students reaching the Median benchmark are also familiar with the use of scales to measure weight or mass. In example item 27, students must interpret a diagram of objects and standard masses on a scale. About 60 percent of fourth-grade students internationally and in the U.S. were able to reason to a conclusion, identifying which of the three objects has the least mass. Again, in Japan and Korea, more than 80 percent of students did so. The use of scales is covered in a number of K–4 content standards in the NSES.

Grade 4 Example 27

From a diagram of objects and standard masses on a scale, reasons to a conclusion to identify which of three objects has the least mass.

Which of the boxes X, Y, or Z has the LEAST mass?



A. X

B. Y

C. Z

D. All three boxes have the same mass.

N09

Percent Correct

★ **United States** 62

▲ **Japan** 87

▲ **Korea** 81

● **International Avg.** 62

FIGURE 6 Grade 4

Lower Quarter International Benchmark — Fourth Grade

Recognize elementary facts presented in everyday language and context about earth's physical features and the solar system, human biology, plant and animal characteristics, life cycles; recognize facts about a range of familiar physical phenomena — rainbows, magnets, soap bubbles, boiling, cooling, floating, dissolving; begin to reason from everyday experience or observation; interpret labeled pictures and simple diagrams.

Students reaching the Lower Quarter benchmark know some basic facts about the earth's physical features and the solar system. They recognize the hottest of earth's layers, that fossils are found in rocks, and that the water in the ocean is salty. They know that the earth moves around the sun and that the sun is hotter than the earth, the moon, or Mars. Students recognize that the moon reflects sunlight. They also interpret a pictorial diagram of the angle/length of shadows cast by sunlight at different times of day.

In life science, students demonstrate knowledge of some basic facts related to human biology and health, including recognizing oxygen as the gas needed for breathing, that air breathed in enters the lungs, that washing hands prevents illness by removing germs, that using sunscreen protects the skin from the rays of the sun, that teeth may be used for grinding, and that rice is edible and cotton is not. Given lists of familiar animals, students can identify those that exhibit specified characteristics such as plant-eating, egg-laying, and milk-producing. They also recognize that increased breathing and heart rate may indicate that an animal is frightened. Students can identify the order of developmental stages of a plant and frog and can identify the butterfly as the adult stage of the caterpillar. From pictorial diagrams, students identify roots as the plant part that takes in water and identify a cactus as a desert plant. Students also can state one reason animals need plants in order to survive and an effect of environmental change (a factory pours hot water into a river) on plant and animal life. They also distinguish living from non-living things and recognize that an apple core decomposes faster than glass, metal, or plastic.

Students recognize a range of everyday physical phenomena, including that loose sugar dissolves faster than sugar cubes, soup stays hot longer in a covered bowl, water changes into vapor during boiling, soap bubbles contain air, magnets attract iron and not aluminum, and sunlight and rain are required to produce rainbows. From a diagram of floating objects, students can identify the heaviest object. They also recognize the order of time measurement units (hour, day, week, month, year).

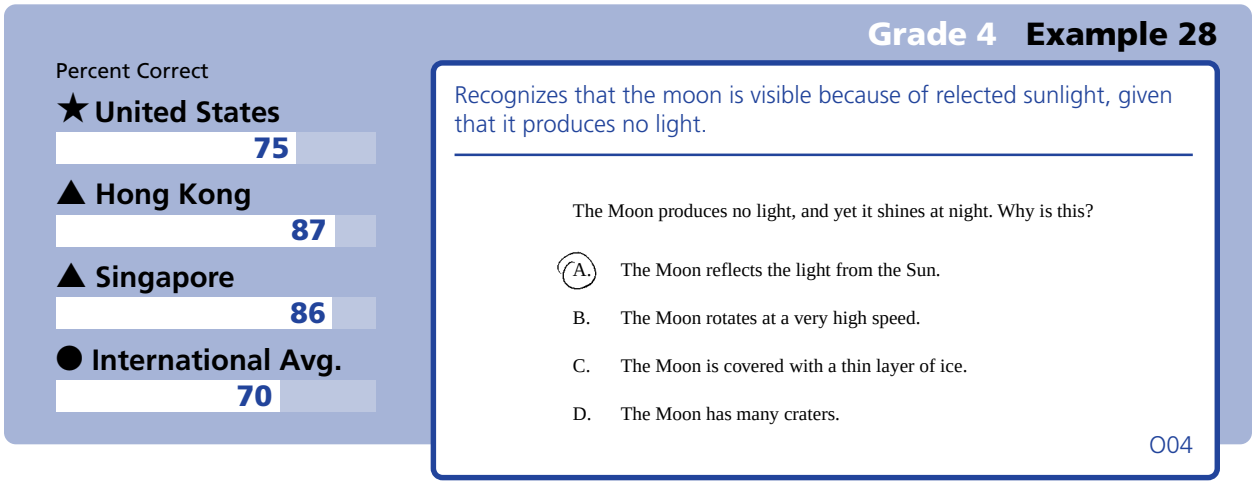
Students interpret labeled pictures and simple diagrams (e.g., earth's layers, shadow angle/length, plant parts, types of trees, human teeth, stages of development of plants and animals). They also demonstrate evidence of reasoning from everyday experience or observation (e.g. relating angle/length of shadows to the time of day, determining relative weights of floating objects, recognizing that soap bubbles contain air).

Fourth-Grade Achievement at the Lower Quarter International Benchmark

Figure 6 describes performance at the Lower Quarter international benchmark for fourth grade. In the U.S., 85 percent of fourth-grade students scored at or above the Lower Quarter international benchmark, 10 percent above the international average.

Earth Science

At the Lower Quarter benchmark, students' knowledge of earth science (as measured by TIMSS) is limited to recognizing some elementary facts involving earth's physical features and the solar system. In example item 28, students are asked to recognize what causes the moon to shine at night even though it does not produce its own light. On average, 70 percent of fourth-grade students chose the correct response. The U.S. performance was 75 percent correct, compared with 87 percent in Hong Kong and 86 percent in Singapore. While U.S. fourth-grade students did fairly well on this item, no relevant standards appear in the NSES document until grades 5–8.



Life Science

Students at the Lower Quarter benchmark demonstrate an awareness of living things but lack some of the understanding shown by students at the higher benchmarks. Although students at the Lower Quarter benchmark exhibited some knowledge of plant and animal life, their understanding of diversity, structure, habitats, and interdependence was limited. Given lists of familiar animals, students at the Lower Quarter benchmark could identify those with specified characteristics and behaviors such as plant-eating, egg-laying and milk-producing. In example item 29, three-quarters of fourth-grade students internationally, and 71 percent of fourth graders in the U.S., identified the monkey as an animal that produces milk. In contrast, nearly all students did so in Korea and Japan.

Example 29 Grade 4

Identifies an animal that produces milk in a list of familiar animals.

Which animal produces milk for its young?

A. Chicken
B. Frog
(C.) Monkey
D. Snake

O07

Percent Correct

★ United States 71
▲ Korea 96
▲ Japan 94
● International Avg. 75

In example item 30, students had to distinguish between living and non-living things to identify the group that contained only living things. The U.S. performed at the international average on this item, with 74 percent correct, while in Japan and Korea, more than 90 percent of fourth-grade students selected the correct response. Developing "basic concepts of living and nonliving" is expected of students in the NSES life science standards at grades K–4.

Example 30 Grade 4

Differentiates between living and non-living things from lists of objects.

Which one of these refers only to living things?

A. clouds, fire, rivers
B. fire, rivers, trees
C. rivers, birds, trees
(D.) birds, trees, worms
E. trees, worms, clouds

N02

Percent Correct

★ United States 74
▲ Japan 94
▲ Korea 91
● International Avg. 74

Knowledge of organisms and their environment is emphasized in the NSES life science content standards for grades K–4. TIMSS items that address some of the concepts described in these standards are answered correctly by students at the Lower Quarter benchmark. For example, students can state one reason why animals need plants to survive. This is directly aligned with the life science standard stating, "All animals depend on plants. Some animals eat plants for food. Other animals eat animals that eat the plants." Another TIMSS item answered correctly by students at the Lower Quarter benchmark requires students to state an effect of environmental change (factory pours hot water into a river). Again, the knowledge of environmental change assessed in this item is directly related to the life science standards. The standards indicate that students should develop understanding that "when the environment changes, some plants and animals survive and reproduce, and others die or move to new locations" and also that "humans change environments in ways that can be either beneficial or detrimental for themselves and other organisms."

Some of the concepts and principles described in the NSES related to organisms and their environment go beyond the items on the TIMSS fourth-grade test. In particular, the standards indicate that students should demonstrate their understanding that "all organisms cause changes in the environment where they live" and that "an organism's patterns of behavior are related to the nature of that organism's environment, including the kinds and numbers of other organisms present, the availability of food and resources, and the physical characteristics of the environment." Items directly addressing these concepts are included in the eighth-grade TIMSS test.

Physical Science

Students at the Lower Quarter benchmark demonstrate familiarity with some physical phenomena but not the understanding of the underlying physical concepts shown by students at the higher benchmark levels. Many of the items answered correctly by students at this level involve reasoning from everyday experience or observations of physical phenomena, such as dissolving, boiling, cooling, the need for sunlight and rain to produce rainbows, angle/length of shadows at different times of day, magnetic properties of familiar materials, and weight of floating objects.[2] While students at this level can identify that loose sugar will dissolve faster than sugar cubes and that soup will stay hot longer in a covered bowl, they typically cannot give an explanation supporting their answer, as was demonstrated by students at the Upper Quarter benchmark in example item 18.

2 All items related to these concepts, and typical of performance at this benchmark, are secure items and therefore cannot be published in this report.

Eighth Grade

International Benchmarks of Science Achievement

Eighth Grade

Eighth Grade

International
Benchmarks of Science Achievement — Eighth Grade

This section describes student performance at each of the four TIMSS international benchmarks for eighth grade and shows examples from the sets of items used to describe performance at each benchmark. For each benchmark, a number of items are presented. These are items that students reaching each benchmark were likely to answer correctly and they represent the kinds of items on which these students typically are successful. For each item, the percent correct is shown for the United States and the highest-performing country, as is the international average percent correct. Because some items will be used in future TIMSS assessments, not all of the items used to develop descriptions of performance are available for display. However, brief descriptions of every item used to develop the benchmark descriptions are provided in the appendix.

FIGURE 7 Grade 8

Top 10% International Benchmark — Eighth Grade

Apply knowledge of the formation of earth's features, the water cycle, and photosynthesis; identify the most abundant gas in air, recognize the basic structure of the atom and that living tissue is made up of atoms and molecules; distinguish between chemical and physical changes; demonstrate understanding of abstract physics concepts, including the effect of light reflection and absorption on the appearance of color, energy efficiency, and constant temperature during phase change; using diagrams, apply basic physical principles to develop explanations and make connections; understand the fundamentals of scientific investigation.

Students reaching the Top 10% benchmark demonstrate and apply knowledge of earth processes and cycles such as formation and erosion of mountains and underground caves, and the relationship between earth's rotation and daily cycle. They recognize the sun as the source of energy for the water cycle and can draw a diagram depicting all steps in the water cycle. They also interpret and apply information in topographical diagrams to identify the direction of water flow from a contour map or to recognize patterns of precipitation from an elevation/temperature diagram. Students identify nitrogen as the most abundant of the gases in Earth's atmosphere.

In life science, students apply knowledge of photosynthesis to describe the importance of light in keeping plants alive in an aquatic ecosystem. They also demonstrate some familiarity with microorganisms in recognizing that bacteria are involved in making yogurt.

Students recognize that the nucleus of an atom is composed of protons and neutrons and that ions are formed by the removal of electrons from atoms . They recognize that cells are made up of molecules and atoms, and that atoms in animals recycle back into the environment after the animals' death . Students also distinguish between chemical and physical changes and between a pure compound and a mixture.

Given data on fuel consumption and work accomplished, students determine which of two machines is more efficient. They explain that mass does not change and temperature remains constant during melting. They recognize that colors appear as they do because of light absorption and reflection.

In an experimental situation, students recognize the variable to be controlled and varied. They also draw a conclusion from a set of observations and describe a simple procedure for investigating the effect of exercise on heart rate.

Students communicate information well and make scientific connections. They provide full written responses to questions requiring two or more answers (e.g., two reasons for uneven availability of water resources; importance of both plants and light in an ecosystem). They also apply basic physical principles to solve quantitative problems and develop explanations involving abstract physical concepts such as the efficiency of machines, conservation of mass and constant temperature during phase change.

Eighth-Grade Achievement at the Top 10% International Benchmark

Figure 7 describes performance at the Top 10% international benchmark for eighth grade. Students reaching this benchmark have demonstrated nearly full mastery of the content of the TIMSS eighth-grade science test. They typically demonstrate success on the knowledge and skills represented by this benchmark, as well as those demonstrated at the Upper Quarter, Median, and Lower Quarter benchmarks. In the U.S., 13 percent of eighth-grade students reached the Top 10% benchmark.

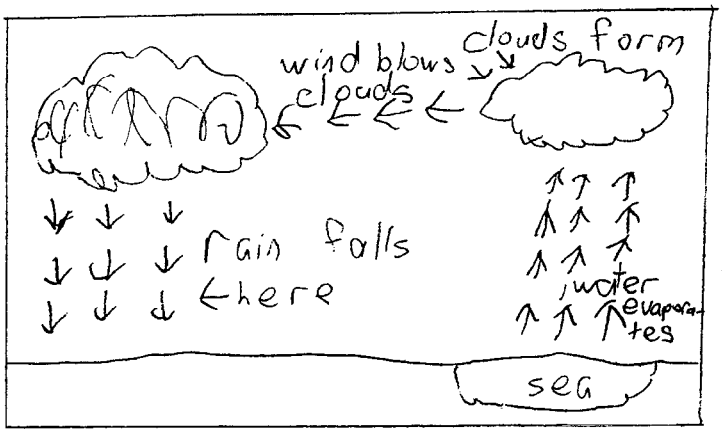
Earth Science

At the Top 10% benchmark, students demonstrate an understanding of earth's processes and cycles, such as formation and erosion of mountains and the water cycle, including the role of the sun's radiation as the source of energy. For example, students at this level could communicate their understanding of the water cycle using a diagram. In example item 1, students had to draw a diagram depicting all steps in the water cycle (evaporation, condensation, transportation, and precipitation) to get full credit. Eighth-grade students in the U.S. performed somewhat above the international average of 32 percent correct, with 40 percent receiving full credit. The top-performing countries were Belgium (Flemish) and the Russian Federation, with about 60 percent correct.

Grade 8 Example 1

Draws a diagram demonstrating knowledge of the Earth's water cycle.

Draw a diagram to show how the water that falls as rain in one place may come from another place that is far away.



W02

Percent Correct

★ United States 40

▲ Belgium (Fl) 60

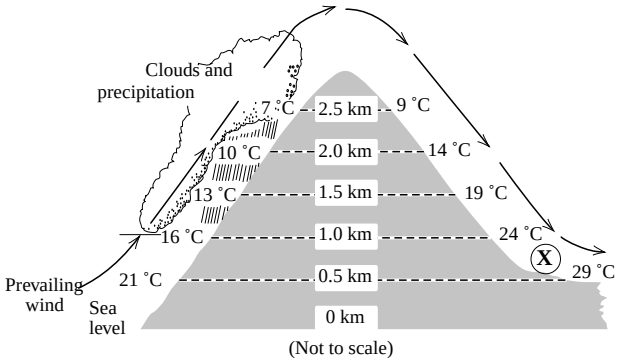
▲ Russian Federation 59

● International Avg. 32

Example 2 Grade 8

Interprets an elevation/temperature diagram and applies knowledge of patterns of prevailing winds and precipitation around a mountain to identify a dry region.

The diagram below shows a mountain. The prevailing wind direction and average air temperatures at different elevations on both sides of the mountain are indicated.



. Which feature is probably located at the base of the mountain at location (X)?

(A.) a dry region

B. a jungle

C. a glacier

D. a large lake

E. a rain forest

B05

Percent Correct

★ **United States**
48

▲ **Hungary**
68

● **International Avg.**
50

Knowledge of patterns of precipitation and water flow were also demonstrated on items requiring students to interpret topographical diagrams. In example item 2, students interpreted a temperature/elevation diagram and applied knowledge of patterns of precipitation around mountain systems. About half of eighth-grade students in the United States and internationally correctly identified the leeward side as a dry region. The top-performing country was Hungary, with 68 percent correct.

According to NSES, by eighth grade, students are expected to understand the water cycle, the rock cycle, land formation and erosion, and weather patterns.

Grade 8 Example 3

Recognizes the relationship between earth's rotation and the daily cycle.

Which statement explains why daylight and darkness occur on Earth?

(A.) The Earth rotates on its axis.

B. The Sun rotates on its axis.

C. The Earth's axis is tilted.

D. The Earth revolves around the Sun.

Q11

Percent Correct

★ United States 52

▲ Korea 77

● International Avg. 44

At the Top 10% benchmark most students recognized the relationship between earth's daily cycle and its rotation (example item 3). While 44 percent of eighth-grade students internationally correctly related daylight and darkness to the rotation of the earth on its axis, almost as many students incorrectly associated the daily cycle with the revolution of the earth around the sun (option D). The NSES document specifies that students in grades 5–8 should develop an understanding of the motions of objects in the solar system and how those motions "explain such phenomena as the day, the year, phases of the moon, and eclipses." It might therefore be expected that by eighth grade nearly all U.S. students would understand the reason for night and day; however, nearly half of them did not, based on their performance on TIMSS. Fifty-two percent of eighth-grade students in the United States demonstrated this level of knowledge of earth's movement in the solar system, compared with 77 percent in Korea.

Grade 8 Example 4

From a list of gases found in air, identifies nitrogen as the most abundant.

Air is made up of many gases. Which gas is found in the greatest amount?

(A.) Nitrogen

B. Oxygen

C. Carbon dioxide

D. Hydrogen

Q12

Percent Correct

★ United States 20

▲ Singapore 58

▲ Japan 54

● International Avg. 27

More than half of the students reaching the Top 10% benchmark identified nitrogen as the most abundant gas in the atmosphere from a list of gases found in air (see example item 4). Overall, 27 percent of eighth graders internationally and 20 percent in the United States could do so. Only in Singapore and Japan did more than half of students answer correctly. A common misunderstanding held by nearly half of students internationally is that oxygen is the most abundant gas in the atmosphere.

According to the NSES content standards, by the eighth grade students are expected to start developing an understanding of the composition of the atmosphere: students should know that "The atmosphere is a mixture of nitrogen, oxygen, and trace gases…" While example item 4 goes somewhat beyond this general guideline, since there is no corresponding standard related to composition of the atmosphere at the grade 9-12 level, knowledge of this fact may be expected by eighth grade. Unfortunately, U.S. students did poorly on the item.

Life Science

Nearly all the life science items on the TIMSS test were answered correctly by students at lower benchmarks, including some items related to the need for light by plant life. However, students did not demonstrate knowledge of photosynthesis, as illustrated by example item 5, until the Top 10% benchmark. Part B of this item requires students to explain the importance of light in the aquarium ecosystem. One-third of eighth-grade students internationally could do this, and of these, about 20 percent mentioned photosynthesis or energy. Performance in the United States was below the international average, with about a quarter of the students providing a correct response to Part B and less than 10 percent explicitly mentioning photosynthesis. In contrast, nearly 80 percent of eighth-grade students in Singapore gave an explanation based on photosynthesis.

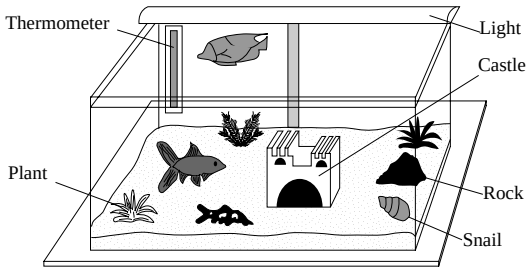
At the grade 5–8 level, the NSES life science standards emphasize developing understanding of ecosystems; it is expected that students will know that "plants and some microorganisms are producers — they make their own food," and that "sunlight is transferred by producers into chemical energy through photosynthesis." The low performance of students in the United States on example item 5 indicates that the majority of eighth-grade students cannot apply the level of understanding specified by the NSES.

Part A of this item was substantially easier for eighth-grade students, with the majority at the Median benchmark being able to explain the importance of plants in maintaining the ecosystem in an aquarium.

Example 5 Grade 8

Part B: Demonstrates knowledge of ecosystems by describing the importance of light in an aquarium.

In the picture of an aquarium, six items are labeled.



Explain why each of the following is important in maintaining the ecosystem in the aquarium.

(a) the plant to give off oxegn and take in carbon dioxide which the animals breath out

(b) the light to help the plant make photosynthesis and make its own food

X02

Part B
Percent Correct

★ **United States** 26

▲ **Singapore** 78

● **International Avg.** 33

Physical Science

Beginning knowledge of the structure of matter is a hallmark of the Top 10% benchmark. The majority of students at this level demonstrated knowledge of the basic structure of the atom by identifying that the nucleus is composed of protons and neutrons and that ions are formed by the removal of electrons from a neutral atom.

According to the NSES physical science content standards for grades 5–8, students should develop an understanding of properties and changes of properties in matter, motions and forces, and transfer of energy. The content standard related to properties of matter indicates that students are not expected to have developed an understanding of structure of matter required by the TIMSS test by eighth grade. In fact, the grade 5–8 standards state that "at this level, elements and compounds can be defined operationally from their chemical characteristics, but few students can comprehend the idea of atomic and molecular particles." Explicit content standards for the structure of matter are not included until grades 9–12 in the NSES physical science standards.

Based on performance on the TIMSS items, students in some countries have covered these topic areas by eighth grade. In many eastern European countries, for example, most students demonstrated knowledge in this area. In contrast to the U.S., where chemistry typically is not treated as a separate subject until the upper secondary level, in other countries it is taught as a separate subject and students are introduced to these concepts by eighth grade. An eighth-grade science curriculum based purely on the standards for the chemical structure of matter defined by the NSES would not prepare U.S. students to perform at the Top 10% benchmark in this content area.

Example 6 Grade 8

Identifies that cells consist of molecules which are made up of atoms.

The words *cloth*, *thread*, and *fiber* can be used in the following sentence: *cloth* consists of *threads* which are made of *fiber.*

Use the words *molecules*, *atoms*, and *cells* to complete the following sentence:

cells _____ consist of molecules _____ which are made of atoms _____ .

J03

Percent Correct

★ **United States** 29

▲ **Bulgaria** 68

▲ **Singapore** 66

● **International Avg.** 32

In example item 6, students recognize the chemical make-up of living matter. Overall, about one-third of eighth-grade students internationally identified that cells consist of molecules which are made up of atoms. While few students in the U.S. and many other countries demonstrated knowledge in this area, more than 60 percent of eighth graders in Bulgaria and Singapore answered correctly.

According to the NSES, eighth-grade students are expected to demonstrate developing knowledge of cells and that "elements combine in a multitude of ways to produce compounds which account for the living and nonliving substances that we encounter." However, understanding the molecular or atomic make-up of cells is not expected until grades 9–12.

Students in the eighth grade found it difficult to distinguish between chemical and physical changes. This understanding was not typically demonstrated by students performing below the Top 10% benchmark (although students at the Upper Quarter benchmark showed some knowledge of chemical change). At the Top 10% benchmark, the majority of students recognized that boiling is not a chemical change. In addition, in example item 7, eighth graders at this level identify a chemical change from descriptions of physical and chemical changes. Internationally, 38 percent of eighth-grade students correctly associated the color change with a chemical reaction. With 42 percent correct, performance in the U.S. was slightly above the international average. The top-performing countries were the Russian Federation and Bulgaria, both with 59 percent correct.

Example 7 Grade 8

From descriptions of physical and chemical changes, identifies a chemical change.

Which is a chemical change?

A. Element 1 is hammered into a thin sheet.

B. Element 2 is heated and turns into a liquid.

(C.) Element 3 turns a greenish color as it sits in air.

D. Element 4 is ground up into a fine, slippery powder.

O11

Percent Correct

★ **United States** 42

▲ **Russian Federation** 59

▲ **Bulgaria** 59

● **International Avg.** 38

According to the grade 5–8 standards, students should know that "a substance has characteristic properties, such as density, a boiling point, and solubility" and that "substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties." While these standards implicitly include the differentiation between physical and chemical changes, they are not explicit with respect to the level of understanding expected at the different grade levels.

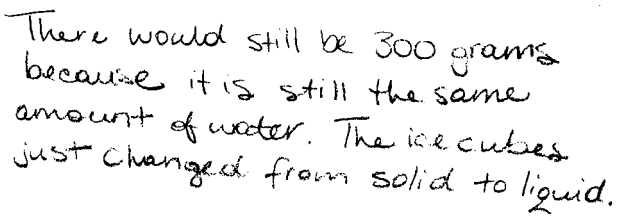
At the Top 10% benchmark, students were able to apply knowledge of abstract concepts and develop explanations based on physics principles. Among these concepts is a basic understanding of phase change. Students reaching this level understood that temperature and total mass remained constant during phase change. In example item 8, internationally and in the U.S., less than one-third of eighth-grade students provided an adequate explanation of the mass of water remaining constant during the change of state. Only in Japan and France did more than half of students do so.

The NSES physical science content standards indicate that grade K–4 students should become familiar with different states of matter and that grade 5–8 students should know that boiling points and melting points are characteristic properties of substances. Explicit standards related to understanding conservation of mass and constant temperature during phase change are not included. The concept of constant temperature during phase change is also not discussed in the physical science standards for grades 9–12.

Grade 8 Example 8

Applies the principle of conservation of mass during phase change to determine and explain the mass of ice after it has melted.

A glass of water with ice cubes in it has a mass of 300 grams. What will the mass be immediately after the ice has melted? Explain your answer.



Q18

Percent Correct

★ United States
32

▲ Japan
56

▲ France
51

● International Avg.
29

Example 9 Grade 8

Applies the principle of efficiency and interprets information in a table to solve quantitative problem and explain which of two machines is more efficient.

Machine A and Machine B are each used to clear a field. The table shows how large an area each cleared in 1 hour and how much gasoline each used.

	Area of field cleared in 1 hour	Gasoline used in 1 hour
Machine (A)	2 hectares	3/4 liter
Machine B	1 hectare	1/2 liter

Which machine is more efficient in converting the energy in gasoline to work? Explain your answer.

Machine A because it did double the amount of work but didn't use double the amount of gasoline.

L04

Percent Correct

★ United States
48

▲ Austria
62

● International Avg.
36

The concept of energy efficiency is very difficult for eighth-grade students, as shown by example item 9. The majority of students at the Top 10% benchmark, however, were able to use the information in the data table to solve the quantitative problem and explain which of the two machines was more efficient. Slightly more than one-third of students internationally explained that Machine A is more efficient based on the ratio of work done to gasoline used. Eighth-grade students in the U.S. performed above the international average on this item, with 48 percent correct, but substantially below Austria (62 percent correct). While NSES physical science standards emphasize developing knowledge of energy transfer by eighth grade, concepts of efficiency and work are not discussed explicitly even for grades 9–12.

Grade 8 Example 10

Applies knowledge of the relationship between absorption/reflection of light and the appearance of color to identify why an object appears blue in white light.

When white light shines on Peter's shirt, the shirt looks blue. Why does the shirt look blue?

A. It absorbs all the white light and turns most of it into blue light.

(B.) It reflects the blue part of the light and absorbs most of the rest.

C. It absorbs only the blue part of the light.

D. It gives off its own blue light.

R02

Percent Correct

★ **United States** 49

▲ **Singapore** 69

● **International Avg.** 40

Students at the lower benchmarks demonstrated basic knowledge of the reflection of light. However, knowledge of the relationship between the absorption and reflection of light and the appearance of color was not shown until the Top 10% Benchmark. In example item 10, students demonstrated some knowledge of the nature of white light and its interaction with matter to produce colors. On average internationally, 40 percent of eighth-grade students recognized that the shirt appears blue because it is reflecting blue light and absorbing the rest, compared to 49 percent in the U.S. and 69 percent in Singapore.

The NSES physical science content standards for grades 5–8 state that students should understand the fundamental concept of the interaction of light and matter: "Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection). To see an object, light from that object — emitted by or scattered from it — must enter the eye." In addition, the standards related to transfer of energy include expectations for students to understand that "the sun's energy arrives as light with a range of wavelengths." The application of knowledge of the visible spectrum to the appearance of color required in example item 10 goes beyond these general standards.

Scientific Investigation

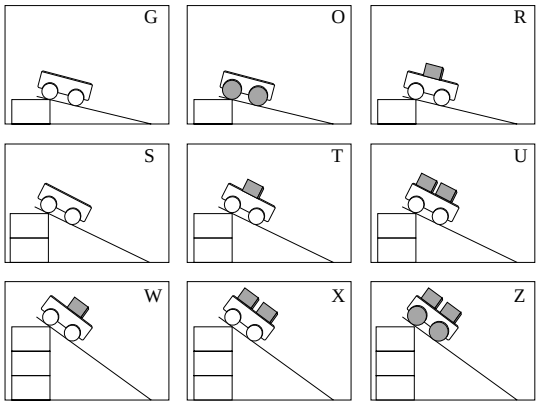
While students at the Upper Quarter benchmark revealed knowledge of some aspects of scientific investigation, skills in this area were more fully developed by students at the Top 10% benchmark. To illustrate, in example item 11, students interpret a diagram depicting experimental trials and recognize the variables to be controlled and varied when conducting an experiment investigating the effect of mass. Only about one-third of eighth-grade students in the United States (32 percent) and internationally (37 percent) answered this correctly. In contrast, about 70 percent of eighth-grade students in Singapore and Japan did.

The NSES expect that by eighth grade, students will be actively engaged in scientific inquiry by designing and conducting investigations. The "Science as Inquiry" content standards state that students should "develop general abilities, such as systematic observation, making accurate measurements, and identifying and controlling variables" and become competent at "communicating scientific procedures and explanations."

Example 11 Grade 8

Applies knowledge of experimental control and interprets diagram to identify variables that must be controlled and varied in a described experiment.

The diagrams show different trials Abdul carried out with carts having different-sized wheels. He started them from different heights and the blocks he put in them were of equal mass.



He wants to test this idea: The heavier a cart is, the greater its speed at the bottom of a ramp. Which three trials should he compare?

A. G, T, and X

B. O, T, and Z

C. R, U, and Z

D. S, T, and U

E. S, W, and X

I12

Percent Correct

★ United States
32

▲ Singapore
71

▲ Japan
69

● International Avg.
37

Designing and communicating an investigation was quite difficult for students in most countries. In example item 12, most students at the Top 10% benchmark described a procedure for investigating the effect of exercise on heart rate that included at least two of three required elements (pre- and post-measurements, exercise step, and use of timing device). Full credit on this item was received by only 14 percent of eighth-grade students internationally and in the United States. In top-performing Singapore, however, about one-third of students provided a complete response.

Despite the emphasis in the NSES on scientific inquiry, performance on some of the TIMSS items reveal that eighth-grade students in the U.S. could improve on their skills and understandings in this area.

Grade 8 Example 12

Describes a procedure for investigating the effect of exercise on heart rate that includes: pre- and post-measurement, exercise step, and use of a timing device.

Suppose you want to investigate how the human heart rate changes with changes in activity. What materials would you use and what procedures would you follow?

materials: stopwatch

procedures: I would have a person sit and then take their pulse.

I would have the person walk, then take their pulse again.

Finally, I would have the person run and take their pulse.

Each time I took their pulse I would time how many ~~beats~~ times per minute their heart was beating

X01

Percent Correct

★ **United States** 14

▲ **Singapore** 32

● **International Avg.** 14

FIGURE 8 Grade 8

Upper Quarter International Benchmark — Eighth Grade

Demonstrate awareness of current environmental issues and basic knowledge about rocks and soil; recognize that plants need minerals and light; understand that burning is a chemical reaction that releases energy; demonstrate beginning knowledge of energy conversions and the composition and chemical properties of matter; apply basic knowledge about light, gravity, and forces to everyday situations; interpret force and ray diagrams; combine sources of information to draw conclusions and provide brief explanations; understand some aspects of scientific investigation.

Students at the Upper Quarter benchmark explain why the ozone layer is important for living things, recognize that increased carbon dioxide in the atmosphere may lead to global warming, describe an unwanted consequence of introducing a new species into an ecosystem, and identify coal as a non-renewable resource. They also recognize the definition of sedimentary rock and interpret a diagram of soil layers to identify the layer with the most organic material.

At this level, students recognize that algae grow near the surface of water where there is light and that plants can extract minerals from decaying fish buried in the ground. They recognize that treating male insects to prevent sperm production would reduce the insect population. Students recognize that maintenance of blood temperature differentiates between warm-blooded and cold-blooded animals, identify the number of legs and body parts characteristic of insects, and name a digestive substance found in the mouth and explain its function.

As well as identifying burning as a chemical reaction, students recognize that burning releases energy and select oxygen from a list of other gases as the one necessary for burning. Students explain how a carbon dioxide fire extinguisher works and why steel bridges must be painted. They recognize that a compound is formed by heating iron and sulfur, that matter is composed of atoms, and that a mixture of mud and water may be separated by filtration.

In physics, students recognize that wood is not a fossil fuel, identify the sequence of energy changes as gasoline burns in an engine, and recognize that most of that energy is lost as heat. They identify the path of light passing through a magnifying lens and explain the use of reflectors to direct the light from a flashlight. Students recognize that gravitational force acts on an object while falling or at rest and interpret a force diagram to predict turning motion. They recognize that the human elbow functions as a lever and describe what happens to the level of water in a watering can when the can is tilted. They complete a brief table showing the relation between voltage and current and explain why a balloon attached to a tube of water will expand as the water is heated.

Based on descriptions of scientific investigations, students distinguish an observation from other types of statements (conclusion, generalization, assumption, hypothesis) and identify an appropriate conclusion. They also recognize that repeated scientific measurements produce similar but not identical results.

Students combine sources of information to make associations and analogies and draw conclusions (e.g., associate the need for light with growth of algae at surface of water; make an analogy between a lever and the human elbow; conclude that an insect population would be reduced by preventing sperm production). They apply scientific knowledge in a practical context to provide brief explanations (e.g., how a carbon dioxide fire extinguisher works, why steel bridges must be painted, how a reflector directs light) and describe consequences (e.g., unwanted result of introducing new species).

Eighth-Grade Achievement at the Upper Quarter International Benchmark

Figure 8 describes performance at the Upper Quarter international benchmark for eighth grade. Students reaching this benchmark typically demonstrate the knowledge and skills represented by this benchmark, as well as those defining performance at the Median and Lower Quarter benchmarks. In the U.S., 30 percent of eighth-grade students scored at or above the Upper Quarter benchmark, slightly above the international percentage.

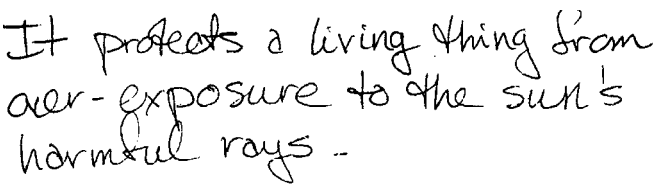
Earth Science

Although knowledge of the uses of some of earth's natural resources was demonstrated by students at lower benchmark levels, it was at the Upper Quarter benchmark that most students demonstrated specific knowledge about sedimentary rocks and soil layers. Students at the Upper Quarter benchmark also showed awareness of current environmental issues such as global warming and the thinning ozone layer. In example item 13, slightly more than half of eighth-grade students internationally and in the U.S. described the importance of the earth's ozone layer in protecting living things from the sun's radiation, most of them referring explicitly to filtration of UV radiation. In Singapore, 78 percent of eighth graders answered the item correctly.

Grade 8 Example 13

Demonstrates knowledge of the function of the ozone layer in filtering the sun's rays by describing its importance for living things.

Write down one reason why the ozone layer is important for all living things on Earth.



R04

Percent Correct

★ United States
52

▲ Singapore
78

● International Avg.
53

While the NSES document does not include explicit earth science content standards related to the importance of the ozone layer, in the "Science in Personal and Social Perspectives" standard there is a general statement about students' understanding that "inventions of a society can result in pollution and environmental degradation and can involve some level of risk to human health or to the survival of other species."

Life Science

Students at the lower benchmark levels demonstrated knowledge of a range of topics covering human biology and the characteristics, behaviors, and interactions of plant and animal species. At the Upper Quarter benchmark, students answered nearly all of the life science items on the TIMSS test correctly, revealing an understanding of some of the more complex life science concepts not demonstrated by most students at the lower benchmarks.

Example 14 Grade 8

Demonstrates knowledge that algae require light and associates the need for light with the growth of algae at the surface of water.

Which BEST explains why green marine algae are most often restricted to the top 100 meters of the ocean?

A. They have no roots to anchor them to the ocean floor.

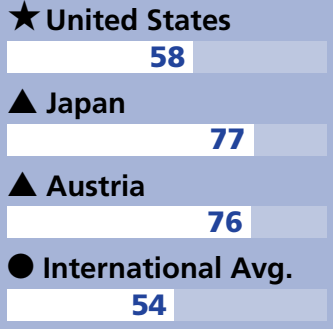
B. They can live only where there is light.

C. The pressure is too great for them to survive below 100 meters.

D. If the algae lived below 100 meters they would be eaten by animals.

L02

Percent Correct



Students at the Upper Quarter benchmark understood the need for light and nutrients for plant growth. In addition, students combined sources of information to make associations and draw conclusions. For example, in example item 14, students demonstrated knowledge that algae require light by associating growth at the surface of water with light. In the U.S., 58 percent of eighth-grade students were able to make this association, compared with 54 percent internationally and more than three-quarters in Japan and Austria.

According to the NSES life science content standards, by eighth grade, students should have developed an understanding of the importance of light energy in ecosystems, and that the organisms supported in an ecosystem depend on "the resources available and abiotic factors, such as quantity of light and water, range of temperatures and soil composition."

Grade 8 Example 15

Recognizes maintenance of internal temperature as the characteristic that differentiates cold-blooded and warm-blooded animals.

How are warm-blooded animals different from cold-blooded animals?

A. Warm-blooded animals have a higher metabolism in warm weather.

B. Warm-blooded animals are more aggressive in captivity.

C. Warm-blooded animals always have a higher blood temperature.

(D.) Warm-blooded animals normally maintain a fairly constant internal temperature at all air temperatures.

E. Warm-blooded animals are found only in warm climates.

J07

Percent Correct

★ United States 63

▲ Japan 86

● International Avg 52

Students reaching the Upper Quarter benchmark demonstrated some knowledge in the area of regulation of biological processes. Example item 15 required students to recognize that maintenance of internal temperature differentiates warm-blooded animals from cold-blooded animals. Internationally, 52 percent of eighth-grade students answered the item correctly, while about 20 percent thought that warm-blooded animals always have higher blood temperatures. Performance in the U.S. was higher than the international average, with 63 percent correct, but still below that of top-performing Japan, with 86 percent.

The NSES life science content standards also emphasize developing an understanding of regulation and behavior of organisms in grade 5–8. These standards state that all organisms must "maintain stable internal conditions while living in a constantly changing external environment" and that regulation involves "changing physiological activities to keep conditions within the range required to survive."

Grade 8 Example 16

Names a digestive substance found in the mouth and explains its function.

What digestive substance is found in the mouth? What does it do?

The mouth has saliva. It makes the food soft so you can swallow and helps break it down.

P06

Percent Correct

★ United States 58

▲ Austria 64

● International Avg 41

Students at the Upper Quarter benchmark demonstrated knowledge of the human digestive system. While students at the Median benchmark could identify saliva as the digestive substance in the mouth (example item 16), students reaching the Upper Quarter benchmark also gave an acceptable explanation of its function. Internationally, only 41 percent of eighth-grade students provided an explanation related to the breaking down, moistening, or softening of food. With 58 percent of eighth graders receiving full credit on this item, performance in the U.S. was substantially above the international average and only somewhat below top-performing Austria (64 percent).

Understanding of the digestive system is included in the NSES document, which emphasizes structure and function in living systems at grades 5–8. It states that students should develop

understanding of the "systems for digestion, respiration, reproduction, circulation, excretion, movement, control, coordination, and protection from disease" in the human organism.

Physical Science

At the Upper Quarter benchmark, students began to demonstrate an understanding of the concept of chemical reactions. While students at the Lower Quarter benchmark knew that oxygen or air is required for rusting and burning, most of those at the Upper Quarter benchmark identified burning as a chemical reaction and knew that it releases energy. In example item 17, students recognize that burning oil releases energy. About 50 percent of eighth-grade students internationally and in the U.S. answered this correctly. In Hong Kong, more than 80 percent did so.

Example 17 Grade 8

Recognizes that burning oil releases energy.

When oil is burning, the reaction will

(A.) only release energy

B. only absorb energy

C. neither absorb nor release energy

D. sometimes release and sometimes absorb energy depending on the oil

M13

Percent Correct

★United States
54

▲Hong Kong
82

●International Avg
51

The NSES physical science standards specify that by fourth grade students should begin to understand that some materials have the "ability to react with other substances." By eighth grade, students' knowledge should be more developed, demonstrating understanding that "substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristics," and that "substances often are placed in categories or groups if they react in similar ways." The knowledge of exothermic and endothermic reactions required for example item 17 is not expected until grades 9–12.

Example 18 Grade 8

Applies knowledge of the need for oxygen/air for burning to explain how carbon dioxide extinguishes a fire.

Carbon dioxide is the active material in some fire extinguishers. How does carbon dioxide extinguish a fire?

A fire needs oxygen to burn so a fire extinguisher sprays out the carbon dioxide to replace the presence of oxygen. Without oxygen, a fire can't burn.

R05

Percent Correct

★United States
62

▲Austria
74

▲England
71

●International Avg
51

In example item 18, students apply knowledge that oxygen is necessary for combustion by explaining that carbon dioxide in fire extinguishers displaces oxygen and prevents it from reaching the fire. About half of eighth-grade students internationally demonstrated this understanding, compared with 62 percent in the U.S. and more than 70 percent in Austria and England.

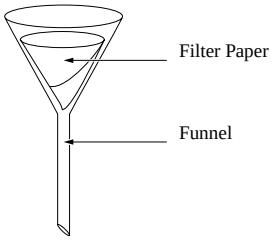
Knowledge of the composition and classification of matter is a hallmark of the Upper Quarter benchmark. In example item 19, students apply knowledge of the process of filtration and the difference between solutions and mixtures to identify the separable heterogeneous mixture.

About half of eighth graders internationally and in the U.S. identified mud and water as a separable mixture, while more than a quarter revealed the misconception that a solution could be separated by filtration (option A or B). In comparison, a high percentage of the eighth-grade students in Korea (88 percent) identified the heterogeneous mixture.

The NSES physical science standards that relate to properties of matter indicate that at eighth grade students should understand that "a mixture of substances often can be separated into the original substances using one or more of the characteristic properties" and include general expectations regarding knowledge of the solubility of substances. However, knowing the definition of a solution and differentiating between homogeneous and separable heterogeneous mixtures is not explicitly discussed. The performance of the U.S. on example item 19 would indicate that many eighth-grade students may need more emphasis on these concepts to reach higher benchmarks on TIMSS.

Grade 8 Example 19

Applies knowledge of the process of filtration and the difference between solutions and mixtures to identify a separable mixture.



Filtration using the equipment shown can be used to separate which materials?

A. A solution of copper sulfate and water

B. A solution of sodium chloride and water

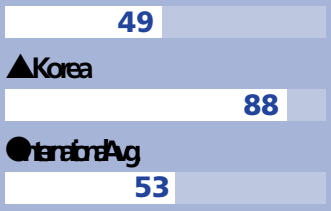
C. A mixture of alcohol and water

D. A mixture of mud and water

E. A mixture of sand and sawdust

N09

Percent Correct



Although concepts related to the transfer of energy receive a fair amount of emphasis in the NSES grade 5–8 physical science standards, many U.S. eighth graders did not demonstrate an understanding of energy conversions. In example item 20, the majority of students at the Upper Quarter benchmark were able to recognize the sequence of energy changes in a diagram as those of gasoline burning in a car. Both internationally and in the U.S. about 60 percent of eighth-grade students responded correctly, compared with more than 80 percent in Singapore.

Example 20 Grade 8

Recognizes that a given sequence of energy changes applies to gasoline burning to power a car.

Chemical Energy	→	Heat Energy	→	Mechanical Energy (with wasted heat)

The sequence of energy changes shown in the diagram explains which event?

A. A flashlight is on.

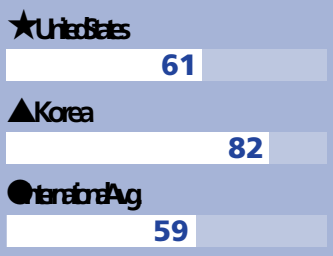
B. A candle burns.

C. Gasoline burns to power a car.

D. Electric current runs a refrigerator.

D04

Percent Correct

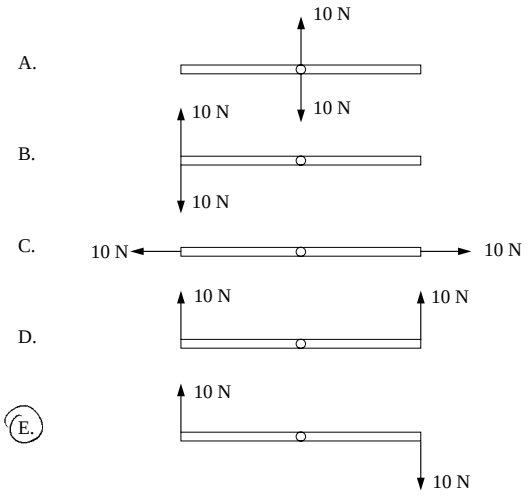


Students at the Upper Quarter benchmark applied knowledge of physics concepts to problem situations and interpreted information in physics diagrams. While students at lower benchmarks demonstrated some practical knowledge of balanced forces, applying this knowledge to interpret the force diagram in example item 21 was much more difficult. In Japan, nearly 80 percent of eighth graders identified the forces that would produce a turning motion. In contrast, in the U.S. as well as many other countries, nearly half or more of eighth-grade students revealed a lack of understanding of balanced forces by selecting options in which no movement of the rod would occur.

Grade 8 Example 21

Interprets diagram of forces acting on a rod and identifies forces that result in turning motion.

A uniform rod is pivoted at its center. It is acted on by two forces in the same plane. Each force has the same size, equal to 10 N (newtons). In which case is there a turning effect?



L01

Percent Correct

★United States
45

▲Japan
78

●International Avg
49

The NSES physical science standards for grades 5–8 state that students should develop an understanding that "if more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude," and that "unbalanced forces will cause changes in the speed or direction of an object's motion." However, the general discussion of developing student understanding also states that "students in grades 5–8 associate force with motion and have difficulty understanding balanced forces in equilibrium, especially if the force is associated with static, inanimate objects." The difficulty of example item 21 would support this.

Example 22 Grade 8

Applies knowledge of gravitational force and recognizes that gravity acts on a falling object at all positions.

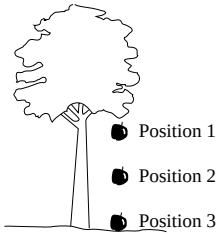
The drawing shows an apple falling to the ground. In which of the three positions does gravity act on the apple?

A. 2 only

B. 1 and 2 only

C. 1 and 3 only

D. 1, 2, and 3



K17

Percent Correct

★United States
64

▲Czech Republic
81

●International Avg
55

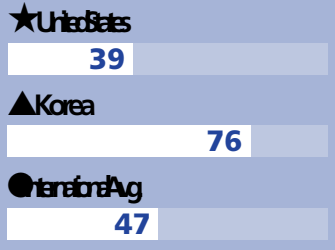
Example item 22 required application of the knowledge of gravitational force to a falling object. On average, just over half of eighth-grade students internationally responded correctly, indicating that gravity is acting on the apple in all positions. Slightly more than a quarter demonstrated the misconception that gravity does not act upon a stationary object when it is on the ground (option B). Performance in the U.S. was higher (64 percent correct) but still well below the Czech Republic, with 81 percent correct. The common misconception reinforces the difficulty many students have with the concept of force without motion.

Conceptual knowledge of gravity is included in the NSES earth science standards for grades 5–8: "Gravity is the force that keeps planets in orbit around the sun and governs the rest of the motion of the solar system. Gravity alone holds us to the earth's surface and explains the phenomena of the tides." Gravitational force is introduced in the NSES as a physics concept at grades 9–12.

The NSES document contains physical science content standards related to the basic interaction of light with matter (reflection, refraction, absorption), and many U.S. students scoring at lower benchmarks demonstrated knowledge of these concepts. The concept of focusing light with lenses and reflectors appeared to be beyond the ability of many eighth-grade students in the U.S. and many other countries. Students at the Upper Quarter benchmark, however, typically could identify the path of light passing through a magnifying glass and, as shown in example item 23, could explain the use of a reflector to direct the path of light. While this item was difficult for students in many countries, more than three-quarters of students in Korea provided an adequate explanation. Internationally, less than half of eighth-grade students, and in the U.S. less than 40 percent, did so.

Grade 8 Example 23

Percent Correct



Applies knowledge of light reflection to explain the use of reflectors to direct the path of light.

Jim and Sandy each make a flashlight from identical batteries and bulbs. Sandy's flashlight contains a reflector, while Jim's does not.

Which flashlight shines more light on a wall 5 meters away? (check one)

____ Jim's

✓ Sandy's

Explain your answer.

With Jim's flashlight, the light goes in all directions. With Sandy's the light is reflected toward the wall.

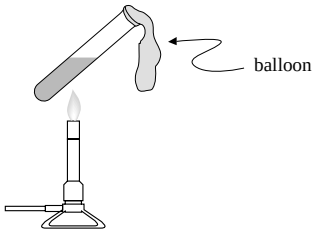
Q12

Students at the Upper Quarter benchmark applied knowledge of the concepts of evaporation and vapor pressure, as illustrated in example item 24. Nearly 60 percent of eighth-grade students internationally could explain why the balloon increases in size when the water is heated, with most referring to evaporation of water into the balloon. Less than half of eighth graders in the U.S. could do so, compared to about three-quarters of students in Israel and Korea. The effect of increasing temperature on vapor pressure is not addressed in the NSES physical science content standards until grades 9–12.

Example 24 Grade 8

Applies knowledge of vapor pressure and thermal expansion to explain the effect of heat/temperature on gas pressure/volume in a practical context.

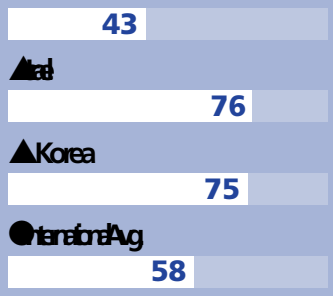
The water in a tube is heated, as shown in the diagram. As the water is heated, the balloon increases in size. Explain why.



As the water is heated it will evaporate and the steam will go up into the balloon making it rise.

P05

Percent Correct



Scientific Investigation

At the Upper Quarter benchmark, eighth-grade students are beginning to demonstrate familiarity with some aspects and terminology of scientific investigation. They typically responded correctly to items requiring them to recognize that repeated scientific measurements produce similar but not identical results and identify an appropriate conclusion or observation based on a description of a scientific investigation.

In example item 25, students were asked to interpret information about a scientific investigation and recognize a reported color change as an observation. Internationally, half of students distinguished the observation from other types of scientific statements, but a large percentage also incorrectly identified the statement as a conclusion. Students in the U.S. performed above the international average, with 62 percent correct, compared with 79 percent in Hungary.

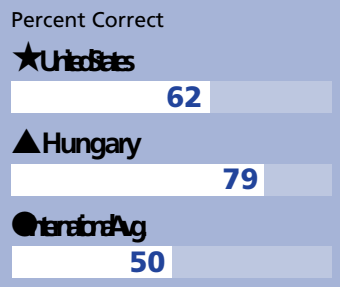
Grade 8 Example 25

Distinguishes an observation from a conclusion, generalization, assumption, or hypothesis.

Maria collected the gas given off by a glowing piece of charcoal. The gas was then bubbled through a small amount of colorless limewater. Part of Maria's report stated, "After the gas was put into the jar, the limewater gradually changed to a milky white color." This statement is

A. an observation
B. a conclusion
C. a generalization
D. an assumption of the investigation
E. a hypothesis

I15



The NSES "Science as Inquiry" content standards state that students should start developing an understanding of scientific observations by fourth grade. By eighth grade, they should be able to develop descriptions using evidence (observation). Although the grade 5–8 standards state that students should be able to "differentiate explanation from description," the definitions of the terms of hypothesis, assumption, and conclusion are not explicitly included and may be beyond the scientific vocabulary of some students. The ability to formulate a hypothesis is not specified in the NSES document until the grade 9–12 level.

FIGURE 9 Grade 8

Median International Benchmark — Eighth Grade

Demonstrate some knowledge of the development and use of earth's natural resources; recognize facts and terminology related to the characteristics of major animal groups, the interdependence among living things, and basic attributes of cells; identify basic properties of light and radiation; apply knowledge of circular motion and thermal expansion; interpret representational diagrams; provide brief descriptive explanations conveying practical knowledge.

Students at the Median benchmark recognize that fossil fuels are formed from dead plants and animals, that overgrazing by livestock can lead to soil erosion, and that a fast-flowing mountain river will flow deeper and slower when it reaches a plain. They also can give one reason for the uneven availability of water for human use.

Students demonstrate some knowledge of the history and characteristics of animal groups, such as identifying a physical characteristic used to sort animals into groups, recognizing milk production as a defining characteristic of mammals, and recognizing that humans have been on Earth a shorter time than some other animal species. They distinguish between warm-blooded and cold-blooded animal species (birds and snakes) and recognize that animals use less energy while hibernating. Students interpret a diagram depicting the oxygen/carbon dioxide cycle in an aquarium, complete a food web diagram, and describe one role of plants in an aquatic ecosystem. They identify cells as the most basic unit of living things and recognize the main function of chloroplasts in plant cells. They also can identify functions of blood and blood cells. Students apply practical knowledge of the function of the human body by describing the advantage of having two eyes, how influenza may be transmitted, and why we get thirsty on a hot day and have to drink a lot.

In physics, students recognize that objects are visible because of reflected light, that light-colored clothes feel cooler because they reflect more radiation, and that ultraviolet radiation from the sun causes sunburn. They also interpret a diagram to identify the change in shadow size resulting from increased distance from a light source. Students recognize that sound cannot travel through space because of the lack of air and that heat will loosen the lid on a glass jar because glass and metal expand at different rates when heated. They interpret a diagram depicting circular motion and recognize that an object will move in a straight line when released from a circular path. They also label the poles on a diagram of a cut magnet.

Students at this level demonstrate a beginning understanding of the principles of scientific measurement by identifying the best thermometer scale for accurately measuring a range of temperatures.

Across the life and physical sciences, students interpret representational diagrams depicting the oxygen/carbon dioxide cycle, a food web, shadow/distance relationships, and circular motion and extract and process more verbal information presented in problem situations.They communicate their practical knowledge through brief descriptive explanations (e.g., the relationship between perspiration and thirst, the transmission of disease, the advantage of two eyes, the importance of plants, and water availability for human use).

Eighth-Grade Achievement at the Median International Benchmark

Figure 9 describes performance at the Median international benchmark for eighth grade. Students reaching this benchmark typically demonstrate success on the knowledge and skills represented by this benchmark, as well as those demonstrated by students at the Lower Quarter benchmark. In the U.S., 55 percent of eighth-grade students scored at or above the Median international benchmark, 5 percent above the international percentage.

Earth Science

At the Median benchmark, students demonstrated knowledge of the development and use of earth's resources beyond that shown by students at the Lower Quarter benchmark. In example item 26, students show they know that fossil fuels are formed from dead plants and animals. Internationally, 62 percent of eighth-grade students overall answered this correctly. In the U.S., 71 percent of eighth graders did so, compared with 87 percent in Ireland.

In example item 27, students at the Median benchmark provided at least one reason for the uneven availability of water for human use. (At the Top 10% benchmark, the majority of students provided two reasons.)

Internationally, 69 percent of eighth-grade students overall provided at least one reason. Students in the U.S. performed above the international average, with 83 percent providing at least one reason, but below top-performing Singapore (93 percent). Providing two reasons was much more difficult for eighth-grade students. Half of students in the U.S. provided two reasons, compared to 37 percent internationally and 62 percent in Singapore.

Grade 8 Example 26

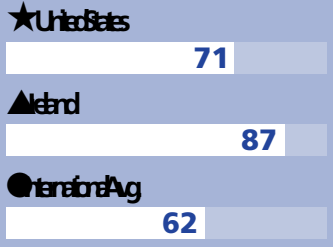
Recognizes that fossil fuels are formed from dead plants and animals.

Fossil fuels were formed from

A. uranium
B. sea water
C. sand and gravel
D. dead plants and animals

K15

Percent Correct



Grade 8 Example 27

Describes at least one reason for the uneven availability of water resources for human usage.

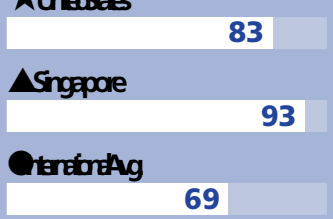
Since water is a renewable resource and so much of it falls each year, theoretically there should be enough water for everyone on Earth. Write down TWO reasons why not everyone has enough water.

1. In some parts of the world like deserts there is not enough water.

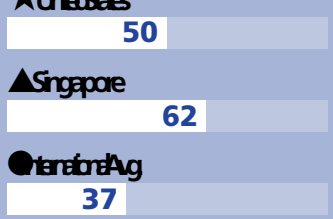
2. A lot of the water on earth is sea water and people cannot drink it.

Z02

At least one reason
Percent Correct



Two reasons
Percent Correct



Life Science

At the Median benchmark, students demonstrated knowledge of the history and characteristics of major animal groups. In example item 28, students showed they know that humans have been on earth for less time than insects, fish or reptiles. With 82 percent correct, performance in the U.S. was close to top-performing Sweden (89 percent) and Denmark (87 percent), and above the international average (66 percent correct). The NSES document contains fairly high expectations of eighth-grade students with respect to the diversity and adaptations of organisms. The life science content standards include some understanding of common ancestry, evolution, adaptation, and extinction. Most of these topics are not addressed by the TIMSS test.

Example 28 Grade 8

From a list of animals, identifies humans as the species on the earth the shortest time.

Which species have been on the Earth for the shortest amount of time?

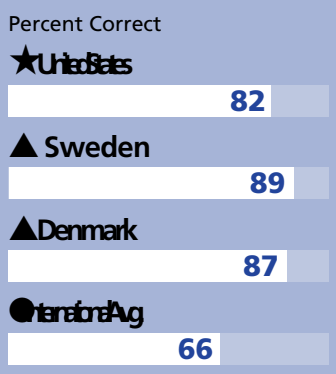
(A.) Humans

B. Insects

C. Fish

D. Reptiles

J02



Grade 8 Example 29

Percent Correct

★United States
71

▲Singapore
94

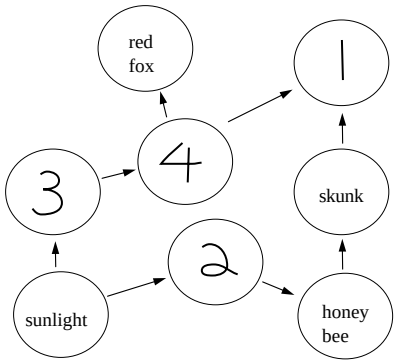
▲Korea
91

●International Avg
68

Applies knowledge of interdependence to complete a food web.

Fill in each circle in this food web with the number of the correct plant or animal from the list. Remember that the arrows point from the energy provider to the energy user.

1. Owl
2. Rose
3. Grass
4. Rabbit



M11

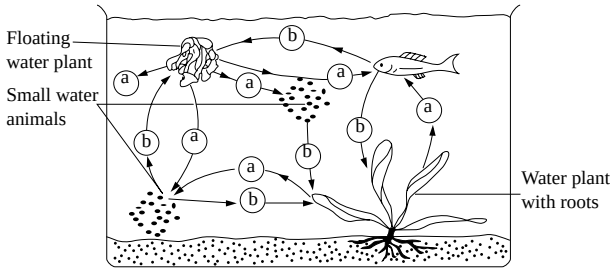
Knowledge of interdependence and ecosystems is a hallmark of the Median benchmark. Most students at this level demonstrated an understanding of energy flow in an ecosystem by completing the food web diagram shown in example item 29. Overall, 68 percent of eighth-grade students internationally and 71 percent of eighth graders in the U.S. correctly completed the diagram. In Singapore and Korea, more than 90 percent of students did so.

In example item 30, students interpreted a diagram depicting the exchange of gases (oxygen and carbon dioxide) in an aquarium. Internationally, 59 percent of eighth-grade students identified the correct gases and direction of exchange between plants and animals. Fifteen percent selected option D; in these cases, the correct gases were identified but the direction of exchange was reversed. The U.S. (59 percent) performed at the international average on this item but substantially below Singapore (91 percent correct).

Example 30 Grade 8

Applies knowledge of oxygen/carbon dioxide cycle to interpret diagram and identify gases used up and given off by plants/animals in an aquarium.

The diagram below shows an example of interdependence among aquatic organisms. During the day the organisms either use up or give off (a) or (b) as shown by the arrows.



Choose the right answer for (a) and (b) from the alternatives given.

A. (a) is oxygen and (b) is carbon dioxide.

B. (a) is oxygen and (b) is carbohydrate.

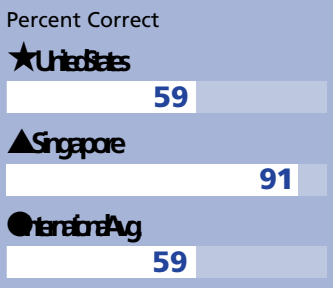
C. (a) is nitrogen and (b) is carbon dioxide.

D. (a) is carbon dioxide and (b) is oxygen.

E. (a) is carbon dioxide and (b) is carbohydrate.

K11

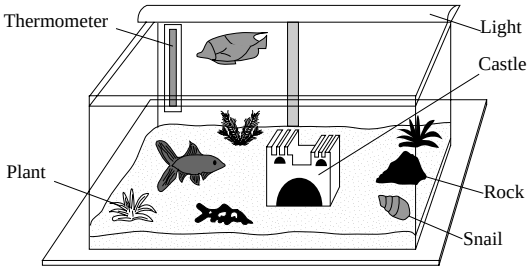
Percent Correct



Grade 8 Example 31

Part A: Demonstrates knowledge of ecosystems by describing one role of plants in an aquarium.

In the picture of an aquarium, six items are labeled.



Explain why each of the following is important in maintaining the ecosystem in the aquarium.

(a) the plant to give off oxegn and take in carbon dioxide which the animals breath out

(b) the light to help the plant make photosynthesis and make its own food

X02

Part A
Percent Correct

★United States	63
▲Singapore	96
●International Avg	64

In example item 31 (Part A), students at the Median benchmark described the importance of the plant in maintaining the aquatic ecosystem. Internationally and in the U.S., slightly more than 60 percent of eighth-grade students provided correct responses; in Singapore, nearly all eighth graders did so (96 percent). The majority of responses internationally related to plants providing oxygen or a food source for the fish. In Singapore, nearly all responses were related to the production of oxygen. Part B, related to the importance of light in the ecosystem, was answered correctly by the majority of students at the Top 10% benchmark, but by few students scoring at lower benchmarks.

The concept of populations and ecosystems is well covered in the NSES life science content standards for grades 5–8. Students are expected to "use food webs to identify the relationships among producers, consumers, and decomposers in an ecosystem." They are also expected to have some understanding of photosynthesis and respiration. Thus, knowledge of the oxygen/carbon dioxide cycle, though not explicitly stated in the NSES standards related to the interdependence of plants and animals, can be inferred.

Example 32 Grade 8

Recognizes light absorption and food production as the main function of chloroplasts in plant cells.

What is the main function of chloroplasts in a plant cell?

(A.) To absorb light energy and manufacture food

B. To remove waste materials by active transport

C. To manufacture chemical energy from food

D. To control the shape of the cell

K18

Percent Correct

★United States
54

▲Japan
89

●International Avg
54

Basic knowledge of the attributes and function of cells is another hallmark of the Median benchmark. Students at this level recognized the cell as the basic unit of living things and also knew some functions performed by cells. In example item 32, students knew that the main function of chloroplasts in a plant cell is to absorb light energy and manufacture food. Internationally and in the U.S., 54 percent of eighth-grade students demonstrated this knowledge, while 89 percent of eighth graders in Japan did so.

Although specific knowledge of chloroplasts is not included in the standards until grades 9–12, the NSES call for students in grades 5–8 to have a fundamental understanding of cells and their functions. Some of the conceptual understandings included in the standards are that "all organisms are composed of cells — the fundamental unit of life;" "most organisms are single cells; other organisms, including humans are multicellular;" "cells grow and divide" and "take in nutrients to provide energy;" and "specialized cells perform specialized functions." The standards also include the concept of levels of organization in living organisms (cells, tissues, and organs). Many of these concepts are not addressed by the TIMSS test.

Example 33 Grade 8

Demonstrates knowledge of contagious disease by describing one way that influenza may be caught.

José caught influenza. Write down one way he could have caught it.

He caught it because he got the germs when someone who had the flu, sneezed on him.

O17

Percent Correct

★United States
61

▲Japan
91

▲ Norway
89

●International Avg
56

Students at the Median benchmark apply practical knowledge to describe the function of human body systems, a concept covered in the NSES grade 5–8 life science standards. In example item 33, students demonstrated knowledge of contagious human disease. Internationally, 56 percent of eighth-grade students described the transmission of disease from an infected person. Eighth-grade students in the U.S. performed slightly above the international average, with 61 percent correct. In Japan and Norway, about 90 percent of eighth graders gave a correct response. The concept of disease resulting from "infection by other organisms" is also covered in the NSES at grade 5–8.

Most students at the Median benchmark also were able to relate thirst and the need for water with perspiration (see example item 34). About 60 percent of eighth-grade students internationally and in the U.S. provided a correct response, compared with more than 90 percent of students in Singapore. This item was also adminstered to fourth graders and was one that the majority of fourth graders reaching the Top 10% benchmark answered correctly (see example 4 for fourth grade).

Grade 8 Example 34

Demonstrates knowledge of the relationship between perspiration and dehydration by describing the reason for thirst on a hot day.

Write down the reason why we get thirsty on a hot day and have to drink a lot.

Because when it is hot out we sweat. Then we have to drink more water because of the sweat that we lose.

O16

Percent Correct

★United States 64

▲Singapore 92

●International Avg 61

Physical Science

While students at the Lower Quarter benchmark demonstrated beginning knowledge of mirrors and reflection, students at the Median benchmark recognized the relationship between light reflection and the visibility of objects. They also recognized that light-colored clothing feels cooler because it reflects more radiation (see example item 35). Internationally, 68 percent of eighth-grade students gave a correct response to this item. The U.S. performance was somewhat below the international average, with 60 percent, while almost 90 percent of eighth graders in the Czech Republic and Singapore answered correctly.

Grade 8 Example 35

Recognizes that a person feels cooler when wearing light-colored clothing because it reflects more radiation.

On a warm sunny day, you will feel cooler wearing light-colored clothes because they

(A.) reflect more radiation

B. prevent sweating

C. are not as heavy as dark clothes

D. let more air in

F02

Percent Correct

★United States 60

▲Czech Republic 88

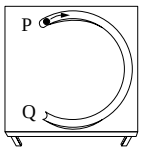
▲Singapore 87

●International Avg 68

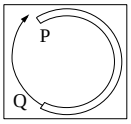
Example 36 Grade 8

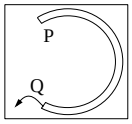
Applies knowledge of circular motion and interprets diagram to identify that an object will move in a straight line when released from a circular path.

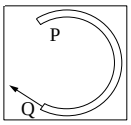
A curved groove is placed on a level table as shown in the diagram. A ball is pushed in the groove at P, so that it leaves at Q.

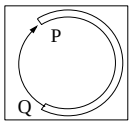


These diagrams show the level table and the groove from above. Which shows how the ball will move when it leaves the groove at Q?

A.


B.


C.


D.


O13

Percent Correct

★ United States 63

▲ Hungary 76

▲ Czech Republic 75

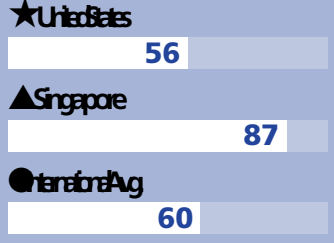
● International Avg 60

Compared with their counterparts at the Lower Quarter benchmark, students at the Median benchmark were able to apply knowledge of an expanded set of physics topics in problem situations, as shown in example items 36 and 37. In example item 36 students applied knowledge of circular motion and interpreted a diagram to predict the motion of a ball released from a circular path. Internationally, 60 percent of eighth-grade students identified that the ball will move in a straight line. The U.S. (63 percent) performed at about the international level, while about three-quarters of eighth-grade students in Hungary and the Czech Republic answered correctly. This item required application of knowledge of a concept included in the NSES grade 5–8 physical science standards: "An object that is not being subjected to a force will continue to move at a constant speed in a straight line."

Students applied knowledge of the relative thermal expansion properties of glass and metal to determine why heat will loosen the lid on a glass jar (example item 37). About 60 percent of eighth graders in the U.S. and internationally indicated that the metal lid expands more than the glass jar, while 87 percent of eighth-grade students in Singapore did so. The thermal expansion properties of different materials are not explicitly addressed in the NSES physical science standards.

Grade 8 Example 37

Percent Correct



Applies knowledge of relative thermal expansion properties of different materials to identify why heat will loosen the lid on a glass jar.

A tight metal lid on a jar of pickles may loosen when it has been held in hot water. This is because the hot water causes the

A. glass jar to contract

B. metal lid to contract

C. glass jar to expand more than the metal lid expands

(D.) metal lid to expand more than the glass jar expands

Q13

FIGURE 10 Grade 8

Lower Quarter International Benchmark — Eighth Grade

Recognize some basic facts from the earth, life, and physical sciences presented using non-technical language, including the earth's physical features and solar system, the function of nerves and the brain, the inheritance of traits, characteristics of plants and animals, physical properties of materials, and the need for oxygen in rusting and burning; demonstrate beginning knowledge of mirrors and light reflection; interpret and use information presented in labeled pictorial diagrams, tables, and graphs; provide short written responses containing a single piece of factual information.

Students at the Lower Quarter benchmark know a few basic facts about the earth's physical features and solar system. For example, they can select the hottest of earth's layers, identify a planetary condition hostile to human life, recognize that there is less oxygen at higher altitudes, and that the moon is visible because of reflected sunlight. Students can give a reason why a wide plain with a river is a good place for farming and recognize that soil erosion is more likely in sloping barren areas.

In the area of human biology, students demonstrate basic knowledge of the function of nerves and the brain for the senses. They recognize that traits are inherited from both parents and transferred through sperm and egg, that exercise leads to increased breathing and pulse rates, that vitamins and minerals are necessary for human nutrition, and that the heart is not found in the abdomen. They also recognize that predators usually have long pointed teeth and that birds sing to mark their territory. They identify the flower as the part of the plant from which seeds develop and explain how to tell the age of a tree by counting its annuals rings.

In chemistry, students know basic facts related to simple oxidation. They recognize that painting an iron surface prevents rusting by keeping oxygen and moisture from coming in contact with the iron and that fanning a fire makes it burn hotter by supplying more oxygen. They explain why placing a glass jar over a lighted candle causes the flame to be extinguished. They also recognize that a powder made up of both black and white specks is likely to be a mixture.

In physics, students interpret a diagram to identify a non-magnetic substance based on the absence of magnetic attraction and recognize that a metal spoon will conduct heat quicker than either a wooden or a plastic spoon. Students also interpret diagrams to identify the correct arrangement of batteries in a flashlight and to compare the electrical conductivity of different metallic and non-metallic materials. They recognize how to position two children of unequal weight to balance a seesaw and make a linear extrapolation from data presented in a distance/time graph. In addition, students recognize that liquids evaporate quickest from containers with the greatest surface area and that a compressed spring has more stored energy than an uncompressed one. Students at this level interpret diagrams to determine the angle of a reflected beam and the apparent position of a reflected image depicted in a three-dimensional representation. They also recognize that white surfaces reflect more light than colored surfaces.

Students extract information from a table to draw conclusions , interpret labeled pictorial diagrams (e.g., earth's layers, reflections in mirrors, battery arrangements, simple circuits, weights on a seesaw, areas of liquid in containers) and extrapolate from data presented in a linear graph. They also provide short written responses to a few questions requiring a single statement of scientific fact (e.g., counting annual rings to determine the age of a tree; oxygen/air is needed for burning, a reason that a plain with a river is good for farming, a planetary condition hostile to human life).

Eighth-Grade Achievement at the Lower Quarter International Benchmark

Figure 10 describes performance at the Lower Quarter international benchmark for eighth grade. Students at this level typically demonstrate the knowledge and skills represented by this benchmark. In the U.S., 79 percent of eighth-grade students scored at or above the Median benchmark, just slightly above the international percentage.

Earth Science

At the Lower Quarter benchmark, students' knowledge of earth science topics included in TIMSS was limited to a few basic facts about the earth's physical features and solar system. In example item 38, students were asked to extract relevant information from a data table of planetary conditions to describe a condition hostile to human life. Internationally, 79 percent of eighth-grade students provided correct responses, most of which stated that there was too little oxygen to breathe or no UV protection from an ozone layer. The U.S. performed somewhat above the international level, with 86 percent. In Singapore, nearly all eighth graders responded correctly (96 percent).

Grade 8 Example 38

Extracts relevant information from a data table of planetary conditions to draw a conclusion and describe a condition hostile to human life.

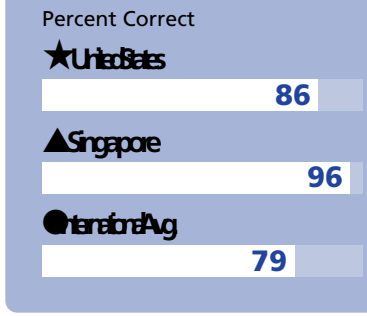
Jane and Mario were discussing what it might be like to live on other planets. Their science teacher gave them data about the Earth and an imaginary planet, Athena. The table shows these data.

	Earth	Athena
Atmospheric Conditions	21% oxygen	10% oxygen
	0.03% carbon dioxide	80% carbon dioxide
	78% nitrogen	5% nitrogen
	ozone layer	no ozone layer
Distance from a Star Like the Sun	148,640,000 km	103,600,000 km
Rotation on Axis	1 day	200 days
Revolution Around Sun	365 1/4 days	200 days

Write down one important reason why it would be difficult for humans to live on Athena if it existed.

People need oxygen to survive and there is not enough oxygen in Athena's atmosphere.

P03



The majority of eighth-grade students at the Lower Quarter benchmark could give one reason why a plain with a river is a good place for farming. The TIMSS item related to this topic was administered at both the eighth and fourth grades, and was answered correctly by most fourth-grade students at the Median benchmark (see example item 21 for fourth grade). Providing a reason why a plain is not a good place for farming was much more difficult. Even at the eighth grade, less than half of students internationally could describe a negative effect such as flooding.

Life Science

At the Lower Quarter benchmark, students demonstrated knowledge of basic facts in human biology involving the function of the respiratory, circulatory and nervous systems, inheritance of traits, and nutrition. In example item 39, students recognized some biological terminology and identified that nerves and hormones carry sensory messages to the brain. In the U.S. and internationally, about 70 percent of eighth-grade students identified the correct answer, compared with 89 percent in the Czech Republic.

Example 39 Grade 8

Recognizes that nerves carry sensory messages to the brain.

Sensory messages are taken to the brain by

A. arteries and veins

B. arteries and hormones

C. nerves and hormones

D. muscles and veins

D05

Percent Correct

★ United States 69

▲ Czech Republic 89

● International Avg 70

Students at the Lower Quarter benchmark also demonstrated some knowledge of the characteristics of plants and animals. In example item 40, students were asked to apply knowledge of the structure and function of animal characteristics to reach a conclusion about features characteristic of predators. Internationally, 71 percent of eighth-grade students correctly identified long, pointed teeth, while 13 percent identified jaws that move sideways. In the U.S., slightly more than the international average responded correctly (75 percent), compared with 84 percent in Austria.

Example 40 Grade 8

Applies knowledge of the structure/function of animal characteristics to identify features belonging to predators.

A girl found the skull of an animal. She did not know what the animal was but she was sure that it preyed on other animals for its food. What clue led to this conclusion?

A. The eye sockets faced sideways.

B. The skull was much longer than it was wide.

C. There was a projecting ridge along the top of the skull.

D. Four of the teeth were long and pointed.

E. The jaws could move sideways as well as up and down.

L03

Percent Correct

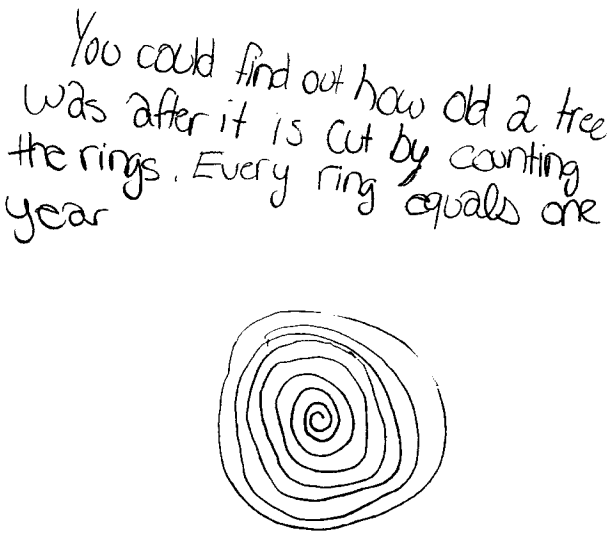
★ United States 75

▲ Austria 84

● International Avg 71

Grade 8 Example 41

Demonstrates knowledge of tree growth by describing how to determine the age of a tree from its annual rings.



J09

Percent Correct

★United States 81

▲ Norway 96

▲ Slovak Republic 96

● International Avg. 75

Some knowledge of the growth and development of plants was demonstrated by students at the Lower Quarter benchmark. Example item 41 required students to describe how the age of a tree can be determined from its annual rings. With 81 percent correct, the U.S. performed above the international average (75 percent correct). In Norway and the Slovak Republic, however, almost all eighth-grade students gave a correct response (96 percent).

Students at the Lower Quarter benchmark also know that seeds develop from the flower of a plant, as illustrated in example item 42. Overall, 73 percent of eighth graders internationally answered this item correctly and nearly all in the Czech Republic and Slovak Republic did. Although life cycles and structures of plants are included in the NSES life science standards for grades K–4, only 59 percent of U.S. eighth graders answered this item correctly. Many U.S. eighth graders who answered this item incorrectly identified the root of the plant as the source of the seeds (27% selected option C), revealing a misconception also held by many fourth-grade students (see example 13 for fourth grade).

Grade 8 Example 42

Recognizes the flower as the part of the plant from which seeds develop.

Seeds develop from which part of a plant?

(A.) Flower

B. Leaf

C. Root

D. Stem

D06

Percent Correct

★United States 59

▲ Czech Republic 95

▲ Slovak Republic 94

● International Avg. 73

Physical Science

Students at the Lower Quarter benchmark demonstrated knowledge of a basic fact related to simple oxidation — the need for oxygen in rusting and burning. In example item 43, students applied knowledge about rusting to a practical situation to identify that iron is painted to prevent exposure to oxygen and moisture. Internationally, 71 percent of eighth-grade students answered this correctly, compared with only 62 percent in the U.S. The highest-performing country on this item was Singapore, with 86 percent correct.

Example 43 Grade 8

Recognizes that painting iron prevents exposure to oxygen and moisture.

Paint applied to an iron surface prevents the iron from rusting. Which ONE of the following provides the best reason?

A. It prevents nitrogen from coming in contact with the iron.

B. It reacts chemically with the iron.

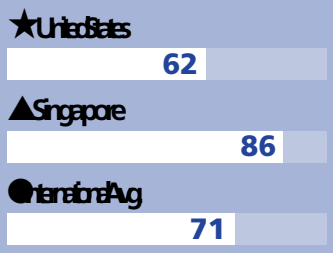
C. It prevents carbon dioxide from coming in contact with the iron.

D. It makes the surface of the iron smoother.

(E.) It prevents oxygen and moisture from coming in contact with the iron.

F06

Percent Correct



Most students at the Lower Quarter benchmark also could describe why a covered candle flame is extinguished in an item also administered to fourth graders (see item 25 for fourth grade). At the eighth grade, most students explicitly mentioned the need for oxygen in their response. In comparison, the majority of responses by fourth graders mentioned only the need for air. While eighth-grade students at the Lower Quarter benchmark demonstrated knowledge of the need of oxygen for burning in this straightforward problem, it was at the Upper Quarter benchmark that students could apply this knowledge to the more complicated item related to carbon dioxide fire extinguishers (see example item 18 for the eighth-grade Upper Quarter benchmark).

The NSES physical science standards do not explicitly call for eighth graders to understand the role of oxygen in rusting and burning, although understanding chemical reactions of substances is addressed in a general way.

Students at the Lower Quarter benchmark demonstrated a beginning knowledge of mirrors and light reflection. In example item 44, students at this level recognized that white surfaces reflect more light than colored surfaces. More than 80 percent of eighth graders internationally and in the U.S., and 95 percent in Belgium (Flemish), answered this item correctly. Students at the Lower Quarter benchmark also were able to determine the apparent position of a reflected image depicted in a three-dimensional diagram and determine the angle of a reflected beam. Reflection of light is discussed in the NSES physical science standards for grades K–4 and 5–8.

Grade 8 Example 44

Recognizes that white surfaces reflect more light than colored surfaces.

The walls of a building are to be painted to reflect as much light as possible. What color should they be painted?

A. White

B. Red

C. Black

D. Pink

B06

Percent Correct

★United States
83

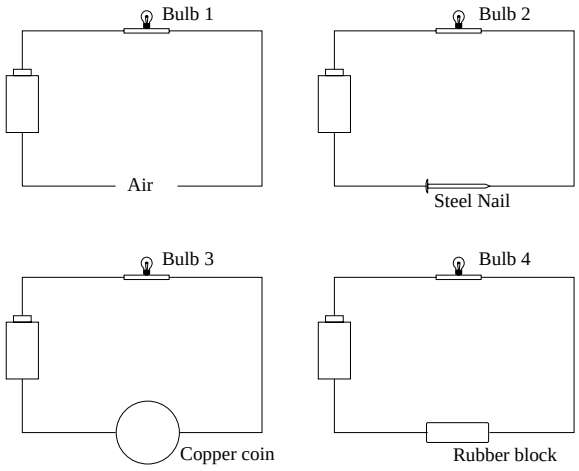
▲Belgium (fl)
95

●International Avg.
85

Example 45 Grade 8

Applies concept of electrical circuits and knowledge of conductors/ insulators to identify the diagrams showing complete circuits made with components of different materials.

The following diagrams show a flashlight battery and a bulb connected by wires to various substances.



Which of the bulbs will light?

A. 1 and 2 only

B. 2 and 3 only

C. 3 and 4 only

D. 1, 2, and 3 only

E. 2, 3, and 4 only

K13

Percent Correct

★United States
78

▲Singapore
97

●International Avg
78

Students at the Lower Quarter benchmark demonstrated practical knowledge of heat and electrical conductivity, magnetism, balanced weights, and evaporation. In example item 45, students were asked to apply knowledge of conductors and insulators and complete circuits. Internationally and in the U.S., slightly more than three-quarters of eighth-grade students knew that only the metals will conduct electricity and complete a circuit. In comparison, nearly all eighth-grade students in Singapore did so (97 percent).

Understandings related to electrical circuits are included in the NSES physical science content standards for grades 5–8.

Knowledge of thermal conductivity of different materials was demonstrated in example item 46, where 84 percent of eighth-grade students internationally knew that metal conducts heat faster than wood or plastic. Eighth graders in the U.S. performed even higher than the international average, with 89 percent, but still below top-performing Singapore (98 percent correct). Understandings related to heat conduction are included in the NSES physical science standards for grades K–4 and 5–8.

Grade 8 Example 46

Recognizes the relative thermal conductivity of different materials based on the sensation of heat.

A metal spoon, a wooden spoon, and a plastic spoon are placed in hot water. After 15 seconds, which spoon will feel hottest?

(A.) The metal spoon

B. The wooden spoon

C. The plastic spoon

D. The three spoons will feel the same.

I16

Percent Correct

★United States 89

▲Singapore 98

●International Avg 84

Example item 47 required students to recognize the relationship between surface area and evaporation rate. About 80 percent of eighth-grade students in the U.S. and internationally correctly identified the container with the largest surface area. Again, 98 percent of eighth-grade students did so in Singapore.

While the NSES physical science standards do not address the concept of surface area versus evaporation rate, it is clear that most eighth-grade students in the U.S. had a practical knowledge of this concept.

Grade 8 Example 47

Percent Correct

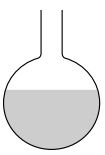
★United States 79

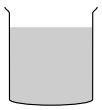
▲Singapore 98

●International Avg 82

Recognizes the relationship between larger surface area and increased evaporation rate.

A student put 100 mL of water in each of these open containers, and let them stand in the sun for one day. Which container probably lost the most water due to evaporation?

A. 

B. 

C. 

(D.) 

K14

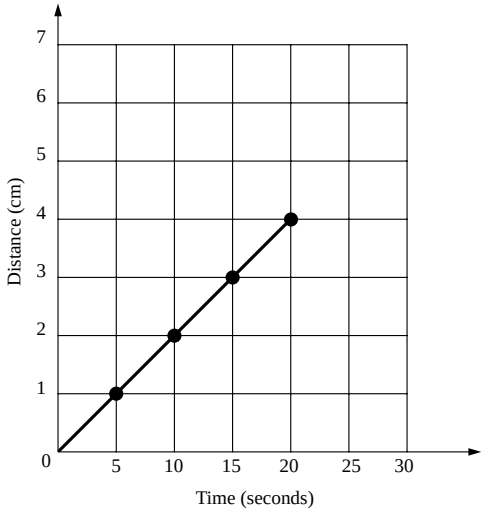
Example item 48 asked students to interpret a graphical representation of motion and extrapolate to determine the distance traveled over a specified time. This is a significant skill demonstrated by the majority of students at the Lower Quarter benchmark. Eighty-three percent of eighth graders internationally, 87 percent in the U.S., and more than 95 percent in France and Singapore answered this item correctly.

According to the NSES physical science content standards, by eighth grade students are expected to understand that "motion can be measured and represented on a graph." With nearly 90 percent correct, it is clear that U.S. eighth graders understood how to interpret and use the data represented in such a graph to solve a problem.

Example 48 Grade 8

Extrapolates from data presented in a distance versus time graph.

The graph shows the progress made by an ant moving along a straight line.



If the ant keeps moving at the same speed, how far will it have traveled at the end of 30 seconds?

A. 5 cm

B. 6 cm

C. 20 cm

D. 30 cm

P01

Percent Correct

★United States 87

▲France 97

▲Singapore 96

●International Avg 83

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Appendix

Descriptions of Items at Each Benchmark: Fourth- and Eighth-Grades

Appendix

Descriptions of Items at Each Benchmark* Grade 4

Lower Quarter Benchmark Items

Earth Science	
A10	Recalls fact about location of fossils in rocks
B02	Recalls information about the saltiness of ocean water
D04	Interprets a diagram of the Earth's layers and identifies the center as the hottest
E06	Recalls knowledge that the sun is the hottest celestial body in the solar system
F02	Recalls knowledge of earth's annual revolution around sun
G07	Interprets pictorial diagram and identifies angle/length of shadow cast by sunlight
O04	Recognizes that the moon is visible because of reflected sunlight, given that it produces no light.

Environmental and Resource Issues	
A07	Identifies a plant not grown for food in a list of familiar edible and inedible plants
E08	Communicates an effect of environmental change (temperature) on aquatic life

Life Science	
B03	Recalls knowledge that plant matter (apple core) will decay
C06	Identifies the herbivore in a list of familiar animals
C08	Identifies oxygen as gas needed for breathing

* Alphanumeric code corresponds to the item cluster in which the item appeared, and the order within the cluster.

Lower Quarter Benchmark Items *continued*

Life Science *continued*	
D02	Interprets diagram and reasons from everyday experience to identify teeth used for grinding
D03	Identifies an animal that does not lay eggs in a list of familiar animals
F01	Identifies a food in a list of edible and inedible plants
G05	Recalls information that air enters the lungs
G06	Interprets diagram and identifies roots as plant part responsible for water uptake
H02	Recognizes that washing hands of germs prevents illness
N02	Differentiates between living and non-living things from lists of objects
O03	Identifies the order of developmental stages of a plant
O07	Identifies an animal that produces milk in a list of familiar animals
P01	Identifies butterfly as the adult stage of caterpillar
P02	Identifies cactus as a desert plant
Q05	Recognizes that an animal's breathing/heart rate may increase when it is frightened
R04	Recalls fact relating the use of sunscreen to protect from sun's radiation
X02	Communicates basic knowledge of food chain by stating one reason animals need plants to survive
X04	Identifies the order of developmental stages of a frog

Item Descriptions Grade 4

Physical Science	
A06	From a diagram of floating objects, identifies the heaviest object
B01	Recalls information about attraction of iron to magnets
E05	Recognizes that air is contained inside soap bubbles
F04	Recognizes order of time measurement units (hour, day, week, month, year)
G09	Recognizes physical conditions required to cause rainbows (sunlight, rain)
H01	Recognizes that water changes into vapor during boiling
W01	Identifies and writes down that loose sugar will dissolve faster than sugar cubes
X01	Identifies and writes down that soup will stay hot longer in a covered bowl than in an uncovered bowl

Median Benchmark Items

Earth Science	
A08	Recalls fact to identify that water covers most of Earth's surface
F03	Interprets textual description and diagrams of rock abrasion observations to identify the hardest rock
Z01A	Demonstrates knowledge of human use of soil and water resources by stating one reason a plain with a river is a good place for farming

Median Benchmark Items *continued*

Environmental and Resource Issues	
O06	Writes down one example of computer uses for work
W05	Communicates knowledge by writing down one example of how people can help reduce air pollution
X03	Communicates knowledge by writing down one harmful effect of oil spills on the environment

Life Science	
A09	Recognizes that excess food is stored as fat
B04	Recognizes that sensory messages are interpreted in the brain
E07	Recognizes that exercise causes an increase in breathing and pulse rates
N05	Associates diagram of webbed foot with aquatic birds
P08	Identifies a feature that differentiates birds from insects
Q01	Identifies the order of the four developmental stages of a butterfly
Q02	Recognizes the nutritional value of fruits and vegetables as a source of vitamins and minerals
Q06	Identifies spider as not being an insect from pictorial representations of familiar species (butterfly, grasshopper, spider, ant)
R07	Interprets diagram to identify damp/dark habitat of worms

Item Descriptions Grade 4

Life Science *continued*	
X05	Applies knowledge of fish characteristics to interpret a 2x2 classification table and identify fish group
Y02	Communicates knowledge by writing one example of physical changes because of human growth and development
Y03	Communicates knowledge of animal behavior by writing one way that animals may protect themselves from danger
Z02	Matches pictures of animals to descriptions of their physical characteristics using basic scientific terminology (outside/inside skeleton, backbone, segments)

Physical Science	
C05	Recognizes that the weight of an object does not change depending on its orientation on a scale
D01	Recognizes that copper is a good heat conductor
N09	From a diagram of objects and standard masses on a scale, reasons to a conclusion to identify which of three objects has the least mass
Q04	Applies knowledge of the relationship between fire/burning and air/oxygen to explain why a covered flame goes out
Q09	Recognizes that heat causes the liquid to expand in thermometers
R05	Applies knowledge to a practical situation to interpret diagram of string telephone and identify condition of string tension required for clear sound transmission
Z03	From a diagram comparing masses on a scale, reasons to a conclusion to determine the heaviest of three objects

Item Descriptions Grade 4

Upper Quarter Benchmark Items

Earth Science	
C09	Recognizes that metals are found in rocks
E09	Demonstrates knowledge that natural phenomena are not entirely predictable
O09	Applies and communicates knowledge of principles of precipitation/temperature as a function of elevation to explain why there is more snow on mountain tops

Environmental and Resource Issues	
C07	Distinguishes between renewable and non-renewable energy sources

Life Science	
P09	Recognizes the flower as the part of the plant from which seeds develop
W02	Communicates knowledge by describing that the heart circulates blood through the body
W04	Communicates knowledge of structure/function in human anatomy to describe an advantage of a thick skull in protecting the brain/head

Item Descriptions Grade 4

Physical Science	
N07	Applies basic knowledge of energy sources to identify food as source of energy for human activity
N08	From its physical description, identifies a heterogeneous powder as a mixture (requires knowledge of scientific terminology)
O05	Interprets reflected light ray diagram and reasons to a conclusion to identify angle of reflected beam
O08	Applies knowledge of magnetic properties by recognizing that a magnet can be used to separate a mixture of iron filings and sand
P05	Applies knowledge of magnetic properties to interpret diagram and identify substance based on its attraction to a magnet
Q03	Recognizes that plastic will break down more slowly than plant/animal matter
W01	Communicates knowledge of physical changes by explaining why loose sugar will dissolve faster than sugar cubes
Z03	From a diagram comparing masses on a scale, reasons to a conclusion to determine the heaviest of three objects and explains answer

Scientific Inquiry and the Nature of Science	
Q07	Recognizes statements that are observations

Top 10% Benchmark Items

Earth Science	
H03	Applies knowledge of earth's features to interpret a diagram and indicate the direction of river flow from mountains to sea
N01	Applies knowledge about weather and freezing point of water to interpret and draw conclusions from data in a temperature/precipitation table

Environmental and Resource Issues	
W05	Communicates two or more examples of how people can help reduce air pollution
X03	Communicates two or more pieces of information related to the harmful effects of oil spills on the environment

Life Science	
N03	Identifies the normal human body temperature
N06	Recognizes that unhatched chicks consume food source that is stored in the egg
O02	Applies knowledge of plant growth to identify that seeds covered with water do not grow due to lack of air
R03	Demonstrates knowledge of plant reproduction by recognizing to identify that offspring are not produced from mixing pollen of incompatible plant species
Y02	Communicates two or more examples of physical changes because of human growth and development
Y03	Communicates knowledge of animal behavior by writing two or more ways that animals may protect themselves from danger

Item Descriptions Grade 4

Physical Science	
O01	Identifies the diagram that shows how to balance two people of unequal weight on a seesaw
P03	Recognizes energy sources
P07	Recognizes the speed of light as faster than sound, airplanes or trains
Q08	Draws the apparent position of a reflected image in a mirror on a diagram representing three dimensions
R08	Distinguishes between a light source and objects that reflect, transmit or focus light
R09	Recalls and applies information about energy sources to recognize advantages of solar energy

Scientific Inquiry and the Nature of Science	
P06	Recognizes the conditions required for a well-designed investigation, given a definition of the problem
R02	Recognizes the importance of making objective measurements in a scientific investigation

Item Descriptions Grade 4

Items Above the Top 10% Benchmark

Earth Science	
G08	Identifies diagram showing correct ratio of visible and submerged volumes of floating iceberg
Z01B	Demonstrates knowledge of human use of soil and water resources by stating one reason a plain with a river is a bad place for farming

Life Science	
H04	Recognizes that a person's adult height is affected by the height of their parents
W03	Demonstrates knowledge of the relationship between perspiration and dehydration by describing the reason for thirst on a hot day

Physical Science	
N04	Interprets diagram and identifies change in buoyancy of object when placed in fresh and salt water
P04	Applies knowledge of mass/weight to interpret diagram and indicates scale reading for combined masses
R01	Demonstrates an understanding that the surface of a liquid remains horizontal by drawing the level of liquid on a frame-of-reference diagram depicting a rotated container
X01	Communicates knowledge of heat and temperature by explaining why soup will stay hot longer in a covered bowl than an uncovered bowl

Descriptions of Items at Each Benchmark* Grade 8

Lower Quarter Benchmark Items

Earth Science	
B01	Interprets a diagram of the Earth's layers and identifies the center as the hottest
E09	Locates point when the temperature becomes colder from data presented in a time and temperature table
F05	Recognizes that there is less oxygen at high altitudes
H03	Recognizes that the moon is visible because of reflected sunlight
P03	Extracts relevant information from a data table of planetary conditions to draw a conclusion and describe a condition hostile to human life
W01A	Demonstrates knowledge of human use of soil and water resources by stating one reason a plain with a river is a good place for farming

Environmental and Resource Issues	
F04	Recognizes that soil erosion is more likely in barren sloping areas

Life Science	
B04	Recognizes that exercise causes an increase in breathing and pulse rates
C08	Recognizes the function of nerves in transmitting visual messages to the brain
D05	Recognizes that nerves carry sensory messages to the brain (requires knowledge of scientific terms)
D06	Recognizes the flower as the part of the plant from which seeds develop

* Alphanumeric code corresponds to the item cluster in which the item appeared, and the order within the cluster.

Lower Quarter Benchmark Items *continued*

Life Science *continued*	
E08	Recognizes that a human inherits traits from both parents
F03	Recognizes that sensory messages are interpreted in the brain
G09	Recognizes that traits are transferred to offspring through the sperm and egg
H02	Recognizes that vitamins are needed by the human body for normal functioning
I10	Recognizes the nutritional value of fruits and vegetables as a source of vitamins and minerals
J09	Demonstrates knowledge of tree growth by describing how to determine the age of a tree from its annual rings
L03	Applies knowledge of the structure/function of animal characteristics to identify features belonging to predators
L05	Recognizes that birds mark their territory by singing

Chemistry	
A09	Applies knowledge of the need of oxygen for burning to a practical situation to identify that fanning a fire provides more oxygen
C10	From its physical description, identifies a heterogeneous powder as a mixture (requires knowledge of scientific terminology)
F06	Recognizes that painting iron prevents exposure to oxygen and moisture
N07	Applies knowledge of the relationship between fire/burning and air/oxygen to explain why a covered flame goes out

Item Descriptions Grade 8

Physics	
A08	Recognizes that a compressed spring has more stored energy than an uncompressed one
B06	Recognizes that white surfaces reflect more light than colored surfaces
C09	Identifies the apparent position of reflected image in a mirror on a diagram representing three dimensions
D02	Applies knowledge of magnetic properties to interpret diagram and identify substance based on its attraction to a magnet
G07	Identifies the diagram depicting the correct arrangement of batteries in a flashlight
I16	Recognizes the relative thermal conductivity of different materials (metals, wood, plastic) based on the sensation of heat
K13	Applies concept of electrical circuits and knowledge of conductors/insulators to identify the diagrams showing complete circuits made with components of different materials (metals, air, rubber)
K14	Recognizes the relationship between larger surface area and increased evaporation rate
M14	Draws the apparent position of a reflected image in a mirror on a diagram representing three dimensions
N08	Applies knowledge of levers to identify the diagram that shows how to balance two people of unequal weight on a seesaw
P01	Extrapolates from data presented in a distance versus time graph
R01	Interprets reflected light ray diagram and reasons to a conclusion to identify angle of reflected beam

Median Benchmark Items

Earth Science	
A12	Applies knowledge of the effect of topography on river flow to identify the change in river shape and speed as it flows from a mountain to a plain
K15	Recognizes that fossil fuels are formed from dead plants and animals

Environmental and Resource Issues	
A11	Recognizes that overgrazing leads to soil erosion
Z02	Describes at least one reason for the uneven availability of water resources for human usage

Life Science	
A07	From a list of organs, identifies the heart as the organ not situated in the abdomen
E10	Determines characteristic used to sort animals into two groups as presented in a 3 x 2 table
F01	Recognizes that feeding milk to its young is a defining characteristic of mammals
G08	Recognizes oxygen transport as the main function of red blood cells
H01	Distinguishes between bodily functions that are carried out by the blood and those that are not
J02	From a list of animals, identifies humans as the species on the earth the shortest time
K11	Applies knowledge of oxygen/carbon dioxide cycle to interpret diagram and identify gases used up and given off by plants/animals in aquarium

Item Descriptions Grade 8

Life Science *continued*	
K18	Recognizes light absorption and food production as the main function of chloroplasts in plant cells
L06	Distinguishes between warm-blooded and cold-blooded animal species (snakes and birds)
M11	Applies knowledge of interdependence to complete a food web diagram
N06	Recognizes the cell as the most basic unit of living things
O16	Demonstrates knowledge of the relationship between perspiration and dehydration by describing the reason for thirst on a hot day
O17	Demonstrates knowledge of contagious disease by describing one way that influenza may be caught
P04	Recognizes the relationship between hibernation and decreased energy consumption
P06	Names a digestive substance found in the mouth
Q17	Demonstrates knowledge of structure/function of organs by describing one advantage of having two eyes
X02A	Demonstrates knowledge of ecosystems by describing one role of plants in an aquarium

Median Benchmark Items *continued*

Physics	
A10	Recognizes the necessity of reflected light for visibility of an object
E11	Applies scientific principle of the effect of distance on shadow size and interprets diagram to solve a quantitative problem involving the change in shadow size when the distance of the light source is increased
F02	Recognizes that a person feels cooler when wearing light-colored clothing because it reflects more radiation
J05	From a list of radiation types, identifies ultraviolet as the form of solar radiation that causes sunburn
L07	Recognizes that the lack of air in space provides no medium for sound transmission
O10	Demonstrates factual knowledge of polarity of magnets by labeling poles on a diagram of a cut magnet
O13	Applies knowledge of circular motion and interprets diagram to identify that an object will move in a straight line when released from a circular path
Q13	Applies knowledge of relative thermal expansion properties of different materials to identify why heat will loosen the lid on a glass jar

Scientific Inquiry and the Nature of Science	
I13	Selects the most appropriate thermometer scale for accurately measuring a given range of temperatures

Item Descriptions Grade 8

Upper Quarter Benchmark Items

Earth Science	
G11	Recognizes a definition of sedimentary rock
H04	Applies knowledge of soil composition and interprets diagram to identify the soil layer containing the most organic material
R04	Demonstrates knowledge of the function of the ozone layer in filtering the sun's rays by describing its importance for living things
W02	Draws a diagram showing at least two steps of earth's water cycle

Environmental and Resource Issues	
C11	Recognizes the relationship between global warming and the increase in carbon dioxide levels in the atmosphere
G12	From a list of renewable and non-renewable energy sources, identifies coal as a non-renewable energy source

Life Science	
I11	Recognizes the number of legs and body parts of insects
I14	Applies basic knowledge of simple machines to draw analogy between a lever and human elbow
J07	Recognizes maintenance of internal temperature as the characteristic that differentiates cold-blooded and warm-blooded animals
K12	Applies knowledge of sexual reproduction to draw a conclusion about preventing sperm production for biological control of insect population

Upper Quarter Benchmark Items *continued*

Life Science *continued*	
L02	Demonstrates knowledge that algae require light and associates the need for light with the growth of algae at the surface of water
N04	Demonstrates knowledge that plants need minerals and associates fertilization of plants with the release of minerals from decomposing animal matter
P06	Names a digestive substance found in the mouth and explains its function
R03	Applies knowledge of ecosystems to describe one unwanted consequence of introducing a new species

Chemistry	
G10	Applies knowledge of the structure of matter to recognize that nothing remains of an object if all of its atoms are removed
H06	Recognizes that burning wood releases energy
J04	From a list of chemical and physical changes, identifies burning as a chemical reaction
J08	From a list of gases, identifies oxygen as the gas needed for burning
M13	Recognizes that burning oil releases energy
N09	Applies knowledge of the process of filtration and the difference between solutions and mixtures to identify a separable mixture
Q14	Recognizes that a compound results from heating a mixture of powdered iron and sulfur

Item Descriptions Grade 8

Chemistry *continued*	
R05	Applies knowledge of the need for oxygen/air for burning to explain how carbon dioxide extinguishes a fire
Z01A	Applies knowledge of rusting in a practical context to explain why steel bridges must be painted
Z01B	Describes one consequence of applying an improved technology in a practical context

Physics	
B02	Applies knowledge of energy conversion in a practical context to identify that an engine converts much of the chemical energy derived from burning gasoline to heat.
C12	Recognizes examples of fossil fuels
D01	Identifies the ray diagram depicting light passing through a magnifying glass
D04	Recognizes that a given sequence of energy changes applies to gasoline burning to power a car
K17	Applies knowledge of gravitational force and recognizes that gravity acts on a falling object at all positions
L01	Interprets diagram of forces acting on a rod and identifies forces that result in turning motion
M12	Recognizes proportional relationship between voltage and current (Ohm's Law) and provides missing information to complete a voltage/current table
N10	Demonstrates an understanding that the surface of a liquid remains horizontal by drawing the level of liquid on a frame-of-reference diagram depicting a rotated container

Upper Quarter Benchmark Items *continued*

Physics *continued*	
P05	Applies knowledge of vapor pressure and thermal expansion to explain the effect of heat/temperature on gas pressure/volume in a practical context
Q12	Applies knowledge of light reflection to explain the use of reflectors to direct the path of light.

Scientific Inquiry and the Nature of Science	
I15	Distinguishes an observation from a conclusion, generalization, assumption, or hypothesis
N03	Reasons from written description of an experiment to identify an appropriate conclusion
P07	Recognizes that repeated scientific measurements should produce similar but not identical results

Item Descriptions Grade 8

Top 10% Benchmark Items

Earth Science	
B05	Interprets an elevation/temperature diagram and applies knowledge of patterns of prevailing winds and precipitation around a mountain to identify a dry region
C07	Applies knowledge of the effect of weathering over time to interpret diagram and draw conclusion about the relative age of two mountain systems based on shape
D03	Interprets a contour map and identifies direction of river flow from higher to lower elevation
E12	From a list of rock types, identifies limestone as the type involved in the formation of underground caves
I17	Recognizes sun's radiation as the energy source for earth's water cycle
J01	Applies knowledge of the continuous formation/erosion of mountains and interprets complex textual information to reason to a conclusion about changes in Earth's surface over billions of years
Q11	Recognizes the relationship between earth's rotation and the daily cycle
W02	Draws a diagram demonstrating knowledge of the Earth's water cycle

Environmental and Resource Issues	
Z02	Describes two or more reasons for the uneven availability of water resources for human usage

Top 10% Benchmark Items *continued*

Life Science	
K16	Recognizes that bacteria are involved in making yogurt
X02B	Demonstrates knowledge of ecosystems by describing the importance of light in an aquarium

Chemistry	
M10	Distinguishes between mixtures and a pure substance (salt)
O11	From descriptions of physical and chemical changes, identifies a chemical change

Physics	
E07	Recognizes that the nucleus of most atoms is composed of protons and neutrons
L04	Applies the principle of efficiency and interprets information in a table to solve quantitative problem and explain which of two machines is more efficient
Q18	Applies the principle of conservation of mass during phase change to determine and explain the mass of ice after it has melted
R02	Applies knowledge of the relationship between absorption/reflection of light and the appearance of color to identify why an object appears blue in white light
Y02	Applies principle of phase change to specify that temperature remains constant during the melting of ice

Item Descriptions Grade 8

Scientific Inquiry and the Nature of Science	
I12	Applies knowledge of experimental control and interprets diagram to identify variables that must be controlled and varied in a described experiment (effect of weight on speed of cart)
I18	Draws conclusion from a set of observations
N01	Applies knowledge of experimental control and interprets diagram to identify variables that must be controlled and varied in a described experiment (effect of soil conditions on plant growth)

Items Above the Top 10% Benchmark

Earth Science	
O12	From a list of gases found in air, identifies nitrogen as the most abundant
Q16	Recognizes that light from the nearest star takes about four years to travel to Earth
W01B	Demonstrates knowledge of human use of soil and water resources by stating one reason a plain with a river is a bad place for farming

Environmental and Resource Issues	
N05	Recognizes gases from burning fossil fuels as a principal cause of acid rain

Life Science	
R03	Applies knowledge of ecosystems to communicate an unwanted consequence of introducing a new species and gives a specific example

Chemistry	
J03	Identifies that cells consist of molecules which are made up of atoms
J06	Recognizes that atoms in animals recycle back into the environment after death
O15	Recognizes that ions are formed from the removal of electrons from atoms
Q15	Recognizes a phase change as not involving a chemical change
Z01B	Describes two consequences of applying an improved technology in a practical context

Item Descriptions Grade 8

Physics	
B03	Uses mass and volume data presented in a table to determine which of four objects has the greatest density
H05	Recognizes that energy stored in food comes from the sun
K10	Demonstrates knowledge of physical properties of air by describing one way to demonstrate its existence
P02	Demonstrates knowledge of light properties by providing an explanation for the same amount of light reaching surfaces at different distances
Y01	Demonstrates knowledge of energy conversion by explaining why the light energy produced by a lamp is less than the electrical energy used
Y02	Applies knowledge of phase change to explain why the temperature of melting ice remains constant

Scientific Inquiry and the Nature of Science	
X01	Describes a procedure for investigating the effect of exercise on heart rate that includes: pre- and post-measurement, exercise step, and use of a timing device