Eisenhower Southwest Consortium for the Improvement of Mathematics and Science Teaching

Classroom Compass

Spring 1997 • Volume 3, Number 3

HIGHLIGHTS

Looking at Classrooms around the World

> *...the TIMSS is the largest, most comprehensive, and most rigorous international study of schools and students ever undertaken.*
>
> Pursuing Excellence, 1996

The TIMSS (Third International Mathematics and Science Study) report, released November 1996, presented the first results from an ambitious cross-national assessment of achievement in mathematics and science education. Students in 41 countries took part in the achievement test. This first report of the lower secondary level population (13-year-old students) will be followed in 1997 by findings on student achievement at fourth grade, and at the end of high school.

TIMSS has many parts. The research design includes assessments, questionnaires, curriculum analyses, videotapes of classroom instruction, and case studies of policy topics. The variety of different and complementary research methods accumulate data, stories, pictures, and analyses that have never been assembled together before. All countries in the study are included in the student assessments, questionnaires, and curriculum analyses. Approximately half of the countries also participated in an additional series of hands-on mathematics and science tasks. To understand the context that contributes to achievement, TIMSS researchers in Germany, Japan, and the United States collaborated to complete videotapes of instruction in eighth-grade mathematics classrooms. Teams of bilingual researchers observed classrooms and interviewed education authorities, principals, teachers, students, and parents for three months in each of the three countries. Topics studied included education standards, methods of dealing with individual differences, the lives and working conditions of teachers, and the role of school in adolescents' lives. Finally, individual states and districts in the United States were offered the opportunity to participate in TIMSS so they could see how their students compare to those of countries throughout the world.

Despite efforts by TIMSS designers to avoid an international horse race, comparisons of

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Looking at Classrooms around the World
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country rankings have been widely discussed in the press, among policy makers, and among researchers. Simply finding out that the students of one nation perform highest on a set of items is not meaningful if performance cannot be systematically linked to some characteristic of a particular educational system. How we interpret and use the results of TIMSS is our challenge. Educators who support educational reform in mathematics and science may glimpse some especially relevant teaching strategies, policies that support curriculum, professional support systems, and student habits that should influence our thinking about effective education. While it may be early to draw conclusions from the information, effective instruction and a coherent curriculum appear to be the strongest contributors to student performance.

U. S. Students and TIMSS

A half million students in 41 countries were examined at three different stages of schooling: midway through elementary school, midway through lower secondary school, and at the end of upper secondary school. Eighth-grade students from the United States placed at about the midway point in mathematics rankings (20 countries ranked significantly higher) and somewhat above midway in science (nine countries ranked significantly higher). The 15,000 participating schools, their curricula, and the educational policies of the countries in the study varied widely. The First in the World Consortium, a group of 20 school districts from Chicago's North Shore, took the TIMSS assessment test with results that placed their students among the highest achieving nations in the world. The Consortium schools credit their success to four areas: the content and rigor of their curriculum, the quality of their instruction, the preparation of their teaching staff, and high performance expectations for their students. If some U. S. schools are performing at the high end of the ranking, however, we can conclude that other schools are faring poorly in their attempts to teach mathematics and science. Several parts of the TIMSS survey examined factors that contribute to students' performance.

What Are We Teaching?

A major component of TIMSS was an extensive, multinational curriculum analysis that yielded data on the mathematics and science curricula of approximately 50 nations. The researchers analyzed mathematics and science textbooks and curriculum guides and used expert data on how topics are introduced, to what extent a topic is covered, and individual content focus in each country. Curricula vary extensively across the world at any given grade level, and caution is needed when interpreting international rankings. The United States is one of nine countries in the study that does not have a centrally coordinated curriculum. (Australia, Denmark, Hungary, Iceland, Latvia, Netherlands, Russian Federation, and Scotland are the others.) Most local school districts in the United States design their own curriculum or standards, usually within broad guidelines issued by each state. Attempting to cover the variety of topics in these diverse curricula, textbooks usually contain much more material than a teacher can effectively teach in a year.

Splintered Vision, a companion study to the TIMSS, bluntly critiques science and mathematics curricula in the United States. The authors note that there is "no single coherent vision of how to educate today's children...nor is there a single, commonly accepted place to turn for such visions." In their analysis of 491 curriculum guides and 628 textbooks, the authors report that U. S. mathematics curricula cover more topics than those in other countries. Topics that are added in grades one and two are repeated until grade seven, and, on the average, topics remain in the U. S. curriculum longer than they do in other countries. As for the reformed classroom, the authors note,

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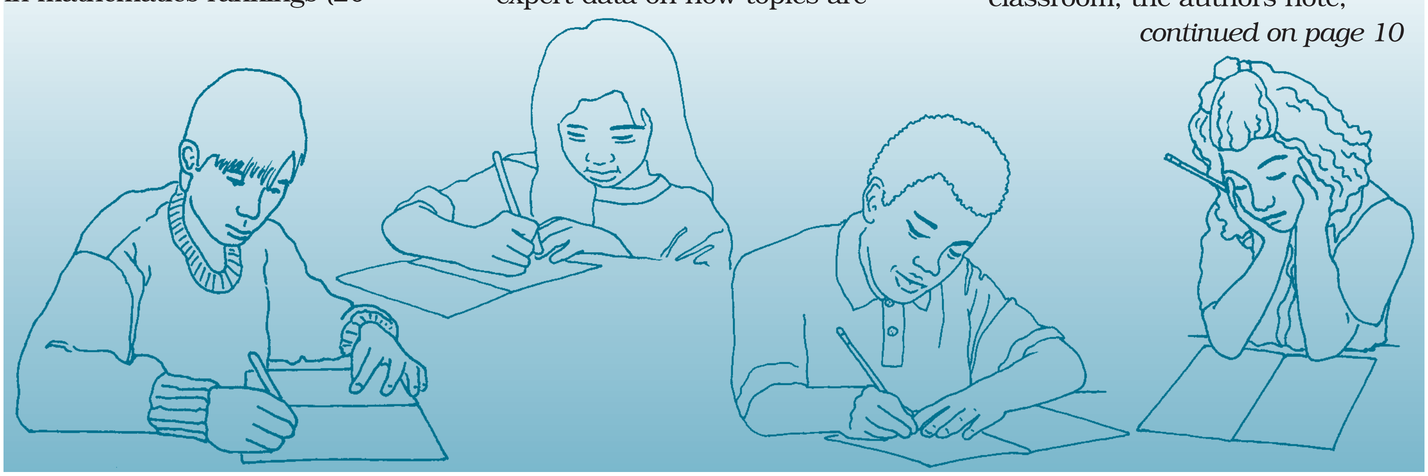

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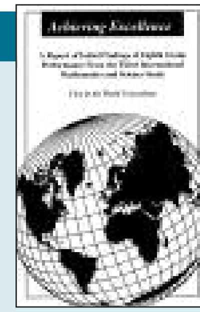

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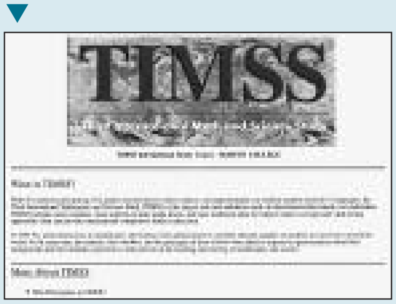
Summary of eighth grade achievement results. (1996, December). ***U.S. National Research Center Report, TIMSS, 7.*** 1–7. (address: 463 Erickson Hall, College of Education, Michigan State University, East Lansing, MI 48824-1034)

U. S. Department of Education. National Center for Education Statistics. (1996). ***Pursuing excellence: a study of U.S. eighth-grade mathematics and science teaching, learning, curriculum, and achievement in international context.*** Washington, D.C.: Author.

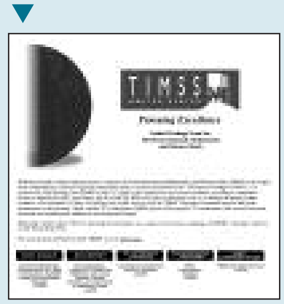
World education league: Who's top? (1997, March 29–April 4). ***The Economist 342,*** 21–23.

Locations on the World Wide Web for more TIMSS information



TIMSS International Study Center at Boston College
http://wwwcsteep.bc.edu/TIMSS

Michigan State University College of Education
http://ustimss.msu.edu/



National Center for Education Statistics, TIMSS home page
http://www.ed.gov/NCES/timss/index.html

International Comparative Studies in Education: Descriptions of Selected Large Scale Assessments and Case Studies
http://www.nap.edu/readingroom/books/icse/study_q.html

Science in the Middle Grades

Benchmarks for Science Literacy provides recommended levels of science understanding for students in grades K–12. In most instances, *Benchmarks* recommends levels for eighth graders that correspond to the TIMSS questions.

The Nature of Science: Scientific Inquiry

At this level students need to become more systematic and sophisticated in conducting their investigations....That means closing in on an understanding of what constitutes a good experiment. The concept of controlling variables is straightforward but achieving it in practice is difficult.

By the end of the eighth grade students should know:
Although there is no fixed set of steps that all scientists follow, scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected data.

The Physical Setting: The Earth

By the end of the eighth grade students should know:
The cycling of water in and out of the atmosphere plays an important role in determining climatic patterns. Water evaporates from the surface of the earth, rises and cools, condenses into rain or snow, and falls again to the surface. The water falling on land collects in rivers and lakes, soil, and porous layers of rock, and much of it flows back into the ocean.

The Physical Setting: Energy Transformations

At this level, students should be introduced to energy primarily through energy transformations. Students should trace where energy comes from (and goes next) in examples that involve several different forms of energy along the way: heat, light, motion of objects, chemical, and elastically distorted materials. To change something's speed, to bend or stretch things, to heat or cool them, to push things together or tear them apart all require transfers (and some transformations) of energy.

The Physical Setting: The Structure of Matter

There seems to be no tidy and consistent way to relate the terms atom, molecule, ion, polymer, and crystal. A facility in discussing these terms will grow slowly over time.

By the end of the eighth grade students should know:
All matter is made up of atoms, which are far too small to see directly through a microscope. Atoms may stick together in well-defined molecules or may be packed together in large arrays. Different arrangements of atoms into groups compose all substances.

The Living Environment: Diversity of Life

Classification systems are not part of nature. Rather, they are frameworks created by biologists for describing the vast diversity of organisms, suggesting relationships among living things, and framing research questions.

By the end of eighth grade, students should know that:
Similarities among organisms are found in internal anatomical features, which can be used to infer the degree of relatedness among organisms. In classifying organisms, biologists consider details of internal and external structures to be more important than behavior or general appearance.

These excerpts are from several portions of *Benchmarks for Science Literacy* by the American Association for the Advancement of Science (AAAS). Available from Oxford University Press.

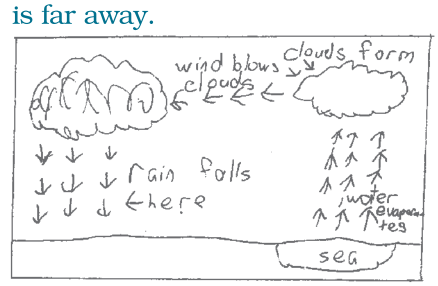
The following are sample items from the eighth-grade component of the TIMSS science segment. The entire science segment also included questions about environmental issues and the nature of science.

Earth Science

Items in the earth science category measure students' knowledge of the scientific principles related to earth features, earth processes, and the earth in the universe. In the Water Cycle question, students were asked to demonstrate their understanding by drawing a diagram. Internationally, students found this item to be rather difficult, with fewer than one-third of the responses showing a fully correct drawing. The next example was the most difficult earth science item. Only about one-quarter of students could identify the correct response—nitrogen gas. The most common misconception, chosen by more than 50 percent of students, was that oxygen is the most abundant gas in air.

Diagram of the Earth's Water Cycle *(U.S. eighth-grade average correct: 40 percent)*

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



Gases in Air *(U.S. eighth-grade average correct: 20 percent)*

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

A. Nitrogen C. Carbon Dioxide
B. Oxygen D. Hydrogen

The TIMSS Science Segment

Life Science

The TIMSS life science questions cover a broad range of content areas related to the structure, diversity, classification, processes, cycles, and interactions of plant and animal life. Internationally, fewer than half of the students selected the correct response about insect features. The heart rate question required students to design and communicate a scientific investigation. Fully correct responses described a procedure in which the pulse is measured at rest using a timer or watch, the individual engages in some type of physical activity, and then the pulse is remeasured during or after the exercise. Across countries, students found this item to be quite difficult, with only 14 percent of eighth-grade students, on average, providing a fully correct extended response.

Insect Features *(U.S. eighth-grade average correct: 44 percent)*

What features do all insects have?

	Number of LEGS	Number of BODY PARTS
A.	2	4
B.	4	2
C.	6	3
D.	8	3

Heart Rate Changes *(U.S. eighth-grade average correct: 14 percent)*

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. Then I'd have them walk and take their pulse again. Then I'd have them run and take their pulse. Each time I took their pulse I would time how many times perminute their heart was beating.

Physics

Topics covered by the physics items include different energy forms, physical transformations, forces and motion, and the properties of matter. Internationally, the students found the flashlight question to be very difficult. This practical problem relates to the nature of light. The students needed to communicate that the same amount of light reaches the wall regardless of the distance the flashlight is from the wall. They may or may not have included the idea that the light becomes more or less spread out. On average, fewer than one-fourth of the students across countries correctly answered this item. A common misconception, identified by more than 30 percent of the student responses, was that a larger area of illumination means there is more light.

Flashlight Shining on Wall
(U.S. eighth-grade average correct: 27 percent)

A flashlight close to a wall produces a small circle of light compared to the circle it makes when the flashlight is far from the wall. Does more light reach the wall when the flashlight is further away?

____ Yes

__✓__ No

Explain your answer.

The same amount of light reaches the wall except when it is close it is all on a smaller area.

Chemistry

The chemistry items measured students' knowledge of topics related to chemical transformations as well as the chemical properties and classification of matter. The item below measured knowledge about the chemical make-up of cells. Internationally students found this short-answer–format item to be quite difficult, with about one-third of the eight-grade students providing the correct response.

Molecules, Atoms, and Cells
(U.S. eighth-grade average correct: 29 percent)

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.

Excerpts from: Beaton, A.E., et al. (1996). *Science achievement in the middle school years: IEA's third international mathematics and science study*. Chestnut Hill, MA: TIMSS International Study Center.

The TIMSS Mathematics Segment

The following are sample items from the eighth-grade component of the TIMSS mathematics segment. These samples represent four content areas examined by the test. The entire mathematics segment also included questions about proportionality and data representation, analysis, and probability.

Fractions and Number Sense

The international averages for this item indicate that working with percentages is a challenge for students in most countries. Only about one-fourth of the students responded correctly to this problem; Singapore students posted the best performance with 78 percent of eighth graders answering it correctly.

Percent Increase in Price

(U.S. eighth-grade average correct: 20 percent)

If the price of a can of beans is raised from 60 cents to 75 cents, what is the percent increase in the price?

A. 15 %
B. 20 %
C. 25 %
D. 30 %

Excerpts from: Beaton, A. E., et al. (1996). *Mathematics achievement in the middle school years: IEA's third international mathematics and science study.* Chestnut Hill, MA: TIMSS International Study Center.

Geometry

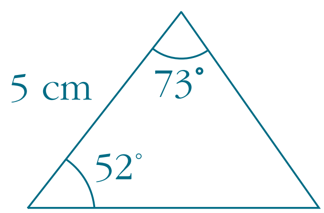
One of the most difficult geometry items assessed understanding of the properties of congruent triangles. Internationally, the average percentage of correct responses was 35 percent for the eighth grade. About two-thirds of eighth-grade students responded correctly in Japan, Korea, and Singapore.

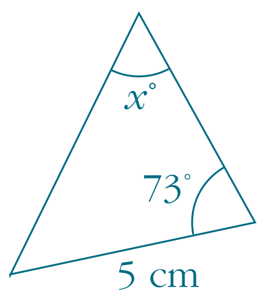
Congruent Triangles

(U.S. eighth-grade average correct: 17 percent)

These triangles are congruent. The measures of some of the sides and angles of the triangles are shown. What is the value of x?

A. 52
B. 55
C. 65
D. 73
E. 75





Algebra

These two examples required the students to work with algebraic expressions and equations. For the first item, students had difficulty recognizing that $m+m+m+m$ is equivalent to $4m$. (Fifty-eight percent of all eighth graders answered this correctly.) It is not surprising that students had even more difficulty identifying the correct expression to represent the number of Clarissa's hats in the next example. International performance on this item averaged 47 percent at the eighth-grade level. Note that the U.S. student scores did not reflect the international ranking for these questions. More U.S. students answered the hat question correctly than the question about equivalent expressions.

Equivalent Algebraic Expressions

(U.S. eighth-grade average correct: 46 percent)

If m represents a positive number, which of these is equivalent to $m+m+m+m$?

A. $m+4$
B. $4m$
C. $m4$
D. $4(m+1)$

Expression Representing Number of Hats

(U.S. eighth-grade average correct: 49 percent)

Juan has 5 fewer hats than Maria, and Clarissa has 3 times as many hats as Juan. If Maria has n hats, which of these represents the number of hats that Clarissa has?

A. $5–3n$
B. $3n$
C. $n–5$
D. $3n–5$
E. $3(n–5)$

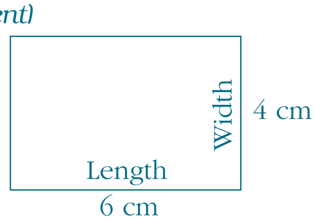
Mathematics in the Middle Grades

Curriculum and Evaluation Standards for School Mathematics from the National Council for Teachers of Mathematics (NCTM) provides recommended levels of mathematics understanding for students in grades K–12. In most instances, the NCTM *Standards* recommends levels for eighth graders that correspond to the TIMSS questions.

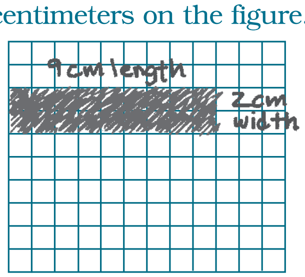
Measurement

In most countries students had difficulty with the first part of this task (drawing a new rectangle)—on average 31 percent of all eighth graders provided a correct drawing. For the second part of the problem, only 10 percent of students internationally provided a correct ratio between the newly drawn and given rectangles.

New Rectangle (*U.S. eighth-grade average correct: 16 percent)*



a. In the space below, draw a new rectangle whose length is one and one half times the length of the rectangle above, and whose width is half the width of the rectangle above. Show the length and width of the new rectangle in centimeters on the figure.



b. What is the ratio of the area of the new rectangle to the area of the first one?

3 to 4

Show your work. *(U.S. eighth-grade average correct: 10 percent)*

$$\frac{\text{New } \Delta = 18\,cm^2 \div 3 = 6}{\text{Old } \Delta = 24\,cm^2 \div 3 = 8} \text{ or } \frac{3}{4}$$

Number and Number Relationships

In grades 5–8, the mathematics curriculum should include the continued development of number and number relationships so that students can— Understand, represent, and use numbers in a variety of forms (integer, fraction, decimal, percent, exponential, and scientific notation). In the middle school years, students come to recognize that numbers have multiple representations, so the development of concepts for fractions, ratios, decimals, and percents and the idea of multiple representations of these numbers need special attention and emphasis. To provide students with a lasting sense of number and number relationships, learning should be grounded in experience related to aspects of everyday life or to the use of concrete materials designed to reflect underlying mathematical ideas.

Geometry

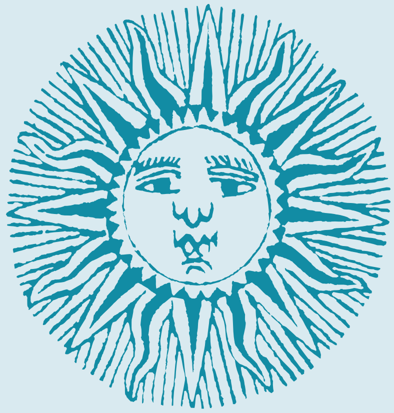
In grades 5–8, the mathematics curriculum should include the study of the geometry of one, two, and three dimensions in a variety of situations so that students can— Identify, describe, compare and classify geometric figures. Students discover relationships and develop spatial sense by constructing, drawing, measuring, visualizing, comparing, transforming, and classifying geometric figures. Discussing ideas, conjecturing, and testing hypotheses precede the development of more formal summary statements. In the process, definitions become meaningful, relationships among figures are understood, and students are prepared to use these ideas to develop informal arguments. The informal exploration of geometry can be exciting and mathematically productive for middle school students.

Algebra

In grades 5–8, the mathematics curriculum should include explorations of algebraic concepts and processes so that students can— Understand the concepts of variable, expression, and equation. Understanding the concept of *variable* is crucial to the study of algebra; a major problem in students' efforts to understand and do algebra results from their narrow interpretation of the term. Many students assign a numerical value to a letter from the start; others ignore the letter, and still others treat the letter as shorthand for an object (*b* means *boy* rather than *number of boys*). Students need to be able to use variables in many ways. Two particularly important ways in grades 5–8 are using a variable as a placeholder for a specific unknown, as in $n + 5 = 12$, and as a representative of a range of values, as in $3t + 6$.

These excerpts are from *Curriculum and Evaluation Standards for School Mathematics.* Order from NCTM, 1900 Association Drive, Reston, VA 22091. Telephone: 1-800-235-7566.

Resources and Opportunities



SUMMER AT THE ZOO

The Bronx Zoo offers an exciting professional development program for teachers nationwide. The zoo's award-winning interdisciplinary K–12 curriculum supports a series of three- to five-day workshops in which teachers are introduced to life science activities that focus on the world of wild animals.

The zoo's program provides staff development and instructional materials to participants for a registration fee of $240. This fee includes lodging in New York City for five days, two meals a day, a refund of 30 percent of air fare (up to $150), and multidisciplinary curriculum materials. Graduate credit is available.

This program is designed to be taken home and used in the teacher's local school. In fact, acceptance into a workshop is contingent upon several requirements, including assurance from a school's principal that the curriculum will be implemented during a specified semester and a commitment from the participating teacher to conduct peer training upon returning home. Preference will be given to teachers from the same school who apply in teams of two or three.

Voyage from the Sun

Grades 4–9

July 24–26, 1997
Exploration of the ways energy is important in living systems

Habitat Ecology Learning Program (HELP)

Grades 4–6

August 4–8, 1997
How nature works, rain forest, wetlands

August 11–15, 1997
Deserts, grasslands, temperate forests

Pablo Python Looks at Animals

Grades K–3

July 21–25, 1997
Interactive lessons about animal shapes, sizes, textures, colors and patterns

Wildlife Inquiry through Zoo Education (WIZE)

Grades 6–8

July 28–August 1, 1997
Module I: Diversity of lifestyles

Grades 7–12

July 28–August 1, 1997
Module II: Survival strategies

For more information call Ann Robinson, manager of national programs at

1-800-937-5131.

SCIMAST

Eisenhower Southwest Consortium for the Improvement of Mathematics and Science Teaching

Eisenhower Southwest Consortium for the Improvement of Mathematics and Science Teaching

The Eisenhower SCIMAST project supports science and mathematics education in five states with a combination of training, technical assistance, networking, and information resources. Eisenhower SCIMAST is funded by the U.S. Department of Education's National Eisenhower Program to serve educators in Arkansas, Louisiana, New Mexico, Oklahoma, and Texas. Eisenhower SCIMAST works in partnership with the Eisenhower National Clearinghouse, a national resource center dedicated to increasing the availability and the quality of information about instructional resources for science and mathematics educators. As part of that effort, Eisenhower SCIMAST has a resource/demonstration center open to visitors Monday through Friday, 8:00 A.M. to 5:00 P.M. The center houses a multimedia collection of science and mathematics instructional materials for grades K–12. It is located on the fourth floor of the Southwest Educational Development Laboratory, 211 East Seventh Street, Austin, Texas 78701. The center also has a toll-free number, **1-800-201-7435**, that provides callers in the five-state region information on multimedia and print instructional materials, assessment tools, and successful strategies for mathematics and science instruction.

Eisenhower SCIMAST Staff:

Glenda Clark, acting director

Sandra Finley, senior training associate

Jackie Palmer, senior training associate

Barbara Salyer, senior training associate

Maria Torres, senior training associate

Mary Jo Powell, technical writing associate

Sharon Adams, information associate

Kathy Schmidt, evaluation associate

Lori Snider, administrative assistant

Veronica Mendoza, administrative secretary

Dawn McArdle, administrative secretary

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"Many reform recommendations simply add to the existing topics (or are implemented by adding to existing content), thereby exacerbating the existing lack of curricular focus."

How Are We Teaching?

The TIMSS videos of eighth-grade mathematics classrooms in Germany (100 classrooms), Japan (50 classrooms), and the United States (81 classrooms) provided glimpses of cultural differences in lesson goals and teaching strategies. A preliminary analysis of the tapes revealed that Japanese teachers, on average, came closer to implementing the spirit of ideas advanced by U. S. reformers than did U. S. teachers.

In the United States and Germany, mathematics teachers tended to present instruction followed by application; the students observed a solution method, then practiced similar examples on their own. The lesson's goal was to solve problems. In Japanese classrooms, the problems were presented and the students spent some time reflecting on them and sharing solutions they generated. Developing an explicit understanding of the underlying mathematical concepts was the goal in those lessons.

The videotapes illustrated other differences. The U. S. lessons were more frequently interrupted (both from outside the classroom and from within) than were the Japanese. Within the same lesson the U. S. lessons contained significantly more topics than did the Japanese. Japanese teachers were more likely to explicitly link different parts of the lesson.

Viewing the lessons by international curriculum standards, the average eighth-grade U. S. lesson dealt with mathematics at a seventh-grade level, the Japanese presented ninth-grade level content, and the German classroom presented content at an eighth-grade level. An independent group of U. S. college mathematics teachers examined the quality of the videotaped lessons' content, basing their evaluations on detailed written summaries that disguised countries of origin. The teachers rated 30 percent of the Japanese lessons as having high content quality, as compared to 23 percent of the German lessons and none of the U. S. lessons. On the other hand, they rated 87 percent of the U. S. lessons as having low content quality.

Other Influences

Surely other factors beyond the curriculum and teaching strategies influence student learning. The TIMSS case studies and questionnaires also examined such variables as time spent in class, levels of teacher preparation, student recreational habits, levels of homework, and the diversity of the student populations. The preliminary findings seem to indicate that in many areas the U. S. culture, schools, teachers, students are not appreciably different from the German and Japanese. For example,

- In Germany, Japan, and the United States 13-year old students seem to spend similar amounts of time with friends engaged in recreational activities, including time spent watching television.
- Severe discipline problems or threats to personal safety are not widespread in or unique to the United States. An approximately equal, and small, number of U. S. and German teachers reported feeling that threats to themselves or their students' safety limited their teaching effectiveness. The Japanese chose not to include any questions relating to problems of discipline or morale.
- U. S. and German teachers assign more homework and spend more time discussing it than do teachers in Japan. When asked about the amount of homework they assign, the most common response of U. S. and German mathematics teachers was that they gave about thirty minutes or less, three or more times a week. The Japanese teachers typically assigned the same amount, but once or twice a week.
- Small class size does not seem to correlate with high achievement in an international context.
- Teachers in the United States and Germany teach more classes a week than do Japanese teachers. In addition, Japanese teachers have more opportunities to learn from each other and share questions about teaching-related issues in formal and informal settings.

More to Come

Analysis of the TIMSS data will continue to emerge. The achievement results of fourth-grade students will be released in the summer of 1997 and that for secondary school students in winter 1997–98. Additional reports will include state-by-state and international comparisons, case studies examining U. S., German, and Japanese educational standards; adolescent life and teachers' working lives; and the complete results of the videotape analysis of eighth-grade mathematics classrooms. These additional studies should sharpen the focus of the emerging picture of mathematics and science learning around the world.