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Lessons from the World:

What TIMSS Tells Us About Mathematics Achievement, Curriculum, and Instruction

What is TIMSS?

The Third International Mathematics and Science Study (TIMSS) is the most comprehensive and most closely monitored international study of math and science achievement to date. TIMSS tells us about education systems and the expectations of countries regarding all of their students and the best of their students. It is not about individual students, teachers, or schools. The American Federation of Teachers (AFT) believes that the TIMSS findings provide valuable information that can be used to improve the quality of American education.

We begin this brief with a review of how the study was conducted and a summary of the findings about student achievement. These findings have received the most attention and provide educators with important data on student performance. The bulk of this brief, however, concerns the less reported and most important findings of TIMSS: the policies and practices that appear to enable high achievement in math and science—and which suggest important policy direction for the U.S. Among other things, TIMSS suggests that a policy push that focuses narrowly on "teacher performance" and not on issues such as standards, curriculum, and teacher development is not likely to succeed.

The study sampled student achievement at three levels:

1. 9-year-olds (U.S. fourth grade)
2. 13-year-olds (U.S. eighth grade), and
3. students in their final year of secondary school (U.S. 12th grade).

Twenty-six countries participated at the fourth-grade level, 41 countries at the eighth-grade level, and 21 countries in the final year of secondary school. There were two goals for the final year of secondary school. One was to find out what students knew when they exited the basic education system, whether they were entering the work force or university. The other was to examine the mathematical knowledge of the top 10 percent to 20 percent of students in each country who take advanced math courses. Sixteen countries assessed "advanced math" students. U.S. advanced math students include those who took either calculus or pre-calculus.

All participating countries were required to administer the assessment at the 13-year-old level. The other age levels were optional. In addition to surveying student achievement, TIMSS gathered extensive information about education systems, curricula, and instruction. It also conducted case studies of the U.S., Japan, and Germany.

Particular attention was focused on eighth-grade mathematics, including a ground-breaking videotape study of classroom instruction in Germany, Japan, and the U.S. New findings continue to be released as more

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analyses of the data are completed.

Criticism regarding the administration of previous international studies led to great care being taken to make sure that TIMSS samples were representative of each country. More than any previous international study, these findings are being used in many school communities to examine policies and practices related to mathematics instruction. It is, therefore, important to examine how these rich findings inform AFT goals for improving education and, in particular, how the TIMSS results can inform the current U.S. debate concerning whether mathematics instruction in the U.S. should go "back to the basics" again or continue with some kind of reform.

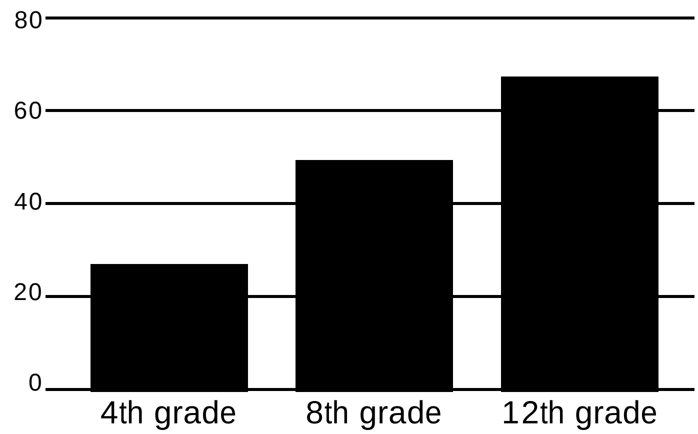
What Did TIMSS Find?

TIMSS examined the achievement data from a number of viewpoints including:

1. Average scores for each country's students. This analysis provides a picture of typical student achievement.
2. The range of scores for each country. Differences between each country's top and bottom students give an indication of how well all students are being educated.
3. The top students in each country. This is an analysis of the top 10 percent of students in the TIMSS sample. If all countries were equal, each would have 10 percent of its students in this group. Alas, this is not the case.

Table 1

Percent of TIMMS countries that significantly outperform the U.S.



Sources:

(Fourth Grade): *Pursuing Excellence: A Study of U.S. Fourth-Grade Mathematics and Science Achievement in International Context* (1997), U.S. Department of Education, National Center for Education Statistics.

(Eighth Grade): *The TIMSS Videotape Classroom Study: Methods and Findings from an Exploratory Research project on Eighth-Grade Mathematics Instruction in Germany, Japan, and the U.S.* (1999), U.S. Department of Education, National Center for Education Statistics.

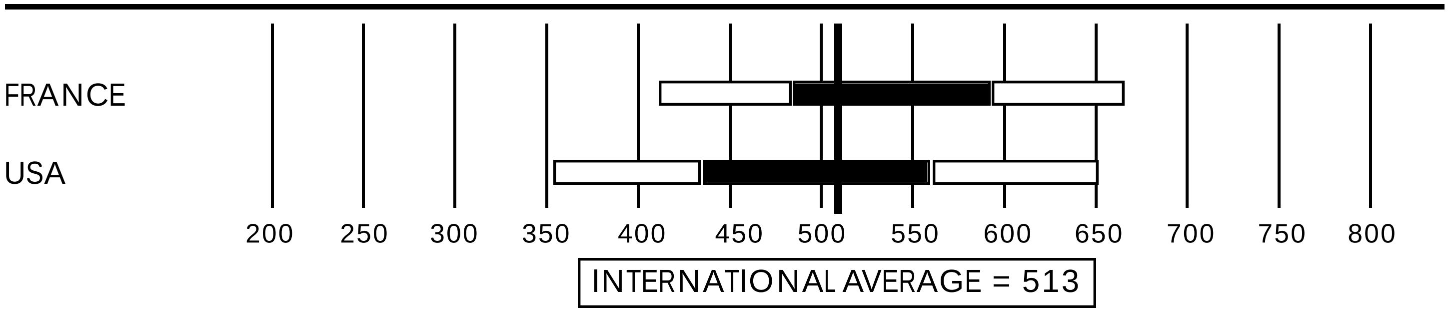
(12th Grade): *Pursuing Excellence: A Study of U.S. 12th-Grade Mathematics and Science Achievement in International Context* (1998), U.S. Department of Education, National Center for Education Statistics.

Average Student Achievement

The picture of U.S. achievement in mathematics is not a happy one. The longer students are in school, the worse their achievement is relative to students in other countries (see Table 1). The chart shows the increasing percentage of participating countries whose students outperform U.S. students.

Table 2

Eighth-grade Math Score Distribution



Source: Mathematics Achievement in the Middle Years: IEA's Third International Mathematics and Science Study (TIMSS) (1996), Beaton, A.E., Mullis, I.V.S., Martin, M.O., Gonzalez, E.J., Kelly, D.L., and Smith, T.A.

In addition to the downward slide when U.S. students are compared internationally as they move through school, TIMSS data reveal that:

- U.S. fourth-graders do as well as the average TIMSS fourth-grader in mathematics, with a mean score slightly above the international average.
- U.S. eighth-graders are significantly below the international mean in math.
- U.S. 12th-grade achievement is among the lowest when compared to TIMSS students in other countries who are in their final year of secondary school. On average, the general population of U.S. students outscored only Cyprus and South Africa. (It is important to note that this is so even though no Asian countries participated in this part of the study.)

Range of Student Achievement

As we have seen, U.S. students as a whole do not excel when compared to their international peers. What is even more disturbing is the wide gap that exists between our best and worst-achieving students, a gap we are striving to close. For example, at the eighth-grade level, the difference between students in the top and bottom 25 percent of those tested is 107 points for France and 128 points for the U.S. (See Table 2.)

In addition, 63 percent of France's eighth-graders are included in the TIMSS top half, but only 45 percent of U.S. students are, an indication that something is working better for a greater percentage of students in France than in the U.S. The larger gap in the U.S. remains until the end of secondary school. The rest of the world (i.e., participating countries) has an average gap of 70 points between all their students and their advanced students in mathematics literacy. For the U.S., the gap is 90 points.

TIMSS Top-Achieving Students

When we compare the top U.S. students to the top students in other countries the picture varies little from the comparison of all students.

- Nine percent of U.S. fourth-graders would be included in a talent pool made up of the top 10 percent of all students who took TIMSS. Not bad.
- But only 5 percent of U.S. eighth-graders would be included in this pool instead of the expected 10 percent. Not good.
- And, the most advanced mathematics students in the United States (only about 5 percent of the 12th-grade cohort), performed similarly to 10 percent to 20 percent of that same cohort in most other countries. Terrible.
- To illustrate the point more graphically, when we look at only the advanced math students in each country, a student in France's bottom quartile may score as well as a student in the U.S. top quartile. Half of the advanced students in the U.S. score below all French advanced students. (See Table 4.) Note the overlap just above the international average between France's 25th percentile scores and the U.S. 75th percentile scores.

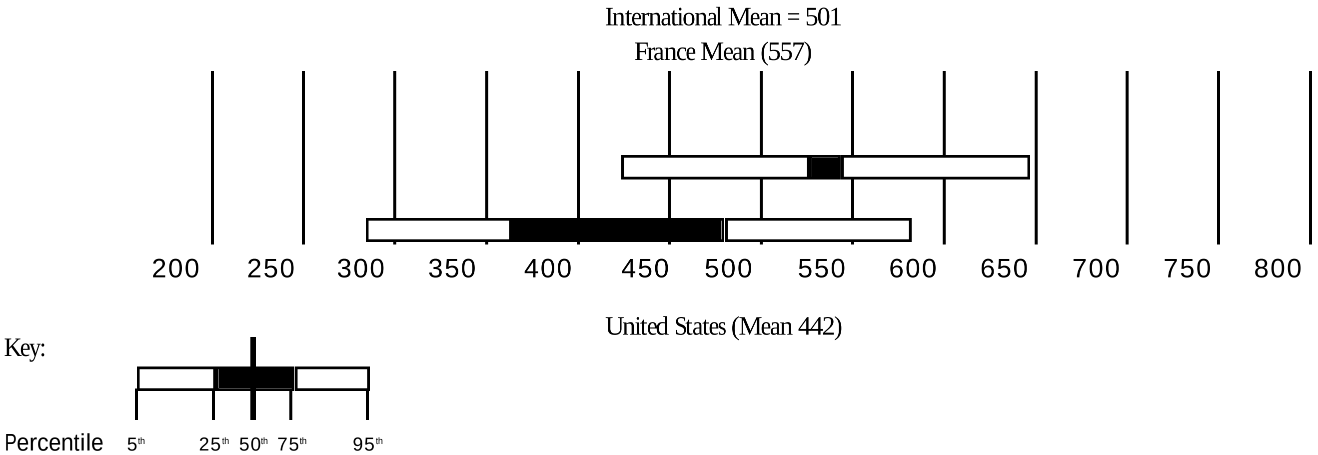
Table 3
Comparison of All Students and Advanced Students in Mathematics and Science Literacy

Country	Mean Achievement: Math and Science Literacy — All students	Math and Science Literacy — Advanced math students	Mathematics Literacy — All students	Mathematics Literacy — Advanced math students
Sweden	555 (4.3)	664(3.7)	661(3.8)	661(3.8)
Switzerland	531 (5.4)	618(4.2)	540(5.8)	619(4.5)
Denmark	528 (3.2)	594(2.9)	547(3.3)	613(3.0)
Canada	526 (2.6)	587(3.7)	519(2.8)	588(3.3)
Australia	525 (9.5)	604(8.1)	522(9.3)	606(7.6)
Austria	519 (5.4)	567(5.9)	518(5.3)	564(6.1)
Slovenia	514 (8.2)	531 (7.1)	512 (8.3)	530 (6.7)
France	505 (4.9)	572 (5.0)	523 (5.1)	592(4.4)
Germany	496 (5.4)	565 (4.1)	495 (5.9)	562 (4.4)
Czech Rep.	476 (10.5)	582 (7.2)	466 (12.3)	573 (7.8)
Italy	475 (5.3)	521 (9.5)	476 (5.5)	519 (10.4)
U.S.	471 (3.1)	554 (5.2)	461 (3.2)	551 (5.1)
Cyprus	447 (2.5)	521 (6.1)	446 (2.5)	516 (6.5)
INTERNATIONAL AVERAGE	505 (1.6)	575 (1.6)	506 (1.7)	576 (1.7)

Source: Mathematics Achievement in the Final Year of Secondary School: IEA's Third International Mathematics and Science Study (TIMSS) (1998), Beaton, A.E., Mullis, I.V.S., Martin, M.O., Gonzalez, E.J., Kelly, D.L., and Smith, T.A.

Table 4

Advanced Math Students Score Distribution



Source: Mathematics Achievement in the Final Year of Secondary School: IEA's Third International Mathematics and Science Study (TIMSS) (1998), Beaton, A.E., Mullis, I.V.S., Martin, M.O., Gonzalez, E.J., Kelly, D.L., and Smith, T.A.

What Does TIMSS Tell Us About Education Systems in Countries with High-Achieving Students?

There are several things that most high-achieving TIMSS countries appear to have in common. But there is no one thing that can be interpreted as a miracle formula for high achievement. Several elements combine in each country to create a coherent *system* that works. Among the commonalities are:

1. A centrally defined set of goals and standards for what students should know.
2. Teachers who are knowledgeable in the subjects they teach. Even in a country such as Singapore, where some primary-grade teachers may not complete four years of college, they *must* pass rigorous subject-matter exams at the end of secondary school in order to be accepted into teacher training. In contrast, approximately one-third of secondary math teachers in the U.S. do not have even a minor in the subject they are assigned to teach, and more than half of those teaching in inner-city schools are ill-prepared.
3. Quality academic programs are in place to prepare those students who will not pursue postsecondary education.
4. More focused curricula. Many TIMSS countries present fewer topics each year than do U.S. schools, thus allowing them to address topics in enough depth so that they do not have to be repeated every year. This enables them to move on to more complex applications and more rigorous content.
5. More rigorous content. The level of content in the U.S. eighth grade equates to seventh-grade curricula elsewhere.
6. No one pedagogy is used across all countries that do well. But, there are some common characteristics of mathematics instruction that is judged likely to lead to high achievement. The TIMSS findings concerning strong instructional lessons in math are summarized in the next section.
7. Alignment of textbooks and curricula with standards and goals.
8. Student accountability for reaching the standards and incentives for high achievement. Meeting standards is key to entry into the most prestigious universities and jobs.

What Have We Learned from TIMSS About Excellent Mathematics Instruction?

One unique feature of TIMSS was a videotape study of classroom instruction. Dr. James Stigler[1] had eighth-grade mathematics lessons in the U.S., Germany, and Japan videotaped. Locations were selected to reflect the diverse settings in each country. Schools were the same ones in which the TIMSS student assessments were administered. Teachers and the class period to be videotaped were selected randomly.

Analysis of the videotapes revealed a high correlation between strong lessons and the following practices. (See Table 5.)

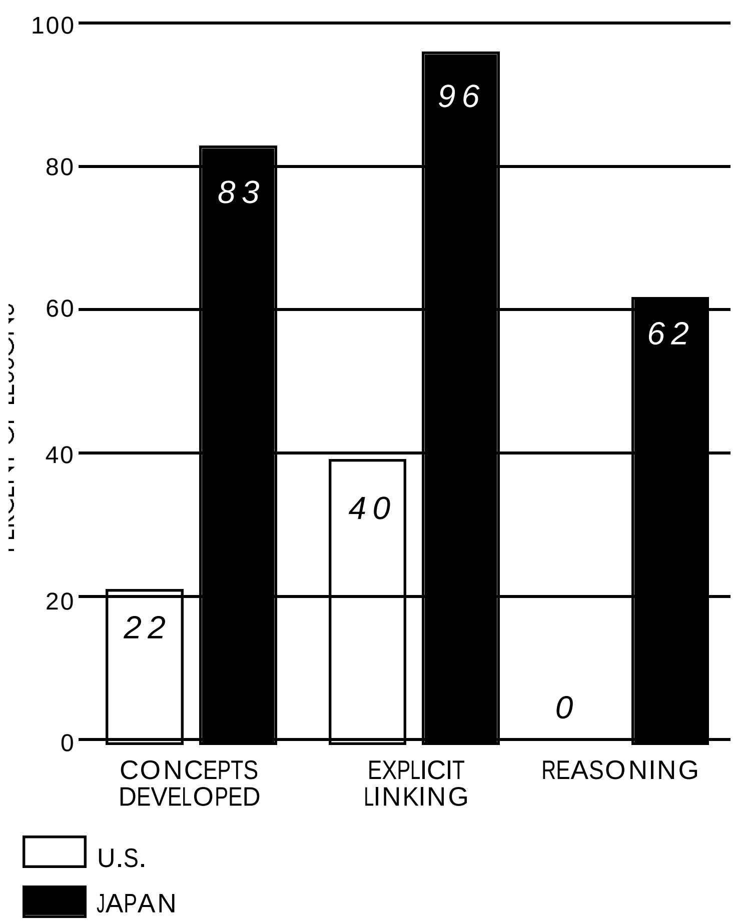
1. The goal of the lesson. Strong lessons were more likely to target mathematical thinking while weak ones were narrower in goal, seeking to teach students how to solve a particular kind of problem or carry out a specific procedure.
2. Treatment of mathematical concepts. In strong lessons, the concepts were far more likely to have been developed rather than simply presented as rules.
3. Multiple solution strategies. Strong lessons included multiple ways to solve problems.
4. Strong lessons were focused and coherent. Weaker ones switched topics significantly more times.
5. Strong lessons included mathematical reasoning. Whether this was formal proof or informal reasoning, mathematical reasoning was explicit.
6. Complexity. The complexity of tasks within a strong lesson was likely to increase.
7. Type of problems. Strong lessons generally asked students to perform tasks that were not “routine.” That is, they weren’t plain calculation or problems for which students just applied a formula that was given to them. In strong lessons, students might have to figure out which formula to use or find more than one way to solve the problem.
8. Connections. In strong lessons, teachers helped students make explicit connections between parts of the lesson to previous knowledge, and/or to statements and problems from earlier parts of the lesson.

These practices are all supported by other research on how children learn and, particularly, on how they learn mathematics.

[1] For more information see, *The Teaching Gap* (1999), Stigler, J. and Hiebert, J. The Free Press: New York, NY.

Table 5

Comparison of some lesson elements that correlate with strong lessons



Source: The TIMSS Videotape Classroom Study: Methods and Findings from an Exploratory Research project on Eighth-Grade Mathematics Instruction in Germany, Japan, and the U.S. (1999), U.S. Department of Education, National Center for Education Statistics.

What Does TIMSS Say about the Usual Recommendations To Boost U.S. Performance—Such as Longer School Days, More Homework, and More Basics?

When talking about the performance of U.S. students, it is common for people to propose magical cures that take the form of more time in school, more homework, and going "back to the basics." TIMSS data, however, show that these are not the solutions for improved math achievement.

1. More time. U.S. students in the lower grades actually reported being in class for math and science for longer periods of time than their counterparts in other countries reported. Thus, *the problem in the earlier years is not the time available or even the time scheduled. It is how that time is used and what level of mathematics is taught.* However, in the final year of secondary school, advanced math and science students in the U.S. reported less class time for science and mathematics than their peers did. In many other countries students were taking two sciences, a practice that generally does not happen here. Many students in other countries reported more than five hours per week in math class.

2. More homework. Eighth-grade students were asked how much homework or studying they did outside of school. Fourth- and eighth-grade students actually reported as much homework as their international peers did.[2] Twelfth-grade U.S. students reported less than other students in their final year of secondary school. The intellectual demands of homework are perhaps as great an issue as the amount of homework. TIMSS found that U.S. teachers assign mostly routine tasks for homework, while Japanese homework places more intellectual demands on students.

3. U.S. students are not falling behind in the basics. Rather, they falter most with multistep problems, mathematical reasoning, geometry, and solving problems that are not routine. *Indeed, the curriculum analyses revealed that U.S. students repeat the basics as they move through the grades rather than being exposed to higher levels of mathematics.* This finding is confirmed by the U.S. National Assessment of Educational Progress (NAEP). Students today outperform their predecessors in basic items that have been administered every year since the early 1970s.

Does TIMSS Shed Any Light on Pedagogy?

The fact that there are high-achieving students who are taught using differing approaches tells us that no single approach can be called *the* right one. Japan believes that students must struggle with problems and find many different ways to solve them. French-speaking Belgium bases math instruction on set theory (the basis of the 1960's New Math). In the Netherlands, math instruction is grounded in real life problems. The French require precision about definitions and language, but also ask that students be able to reason mathematically and draw conclusions from more than definitions. Students in all these countries outperform U.S. pupils.

Researcher James Stigler says that his videotape study found that "in many ways Japanese teaching resembled the recommendations of the U.S. reform movement more closely than did American teaching,"[3] but that "they're more teacher directed than you get the sense of from what the NCTM standards seem to recommend. These are lessons that are clearly highly controlled by the teacher."

What is clear: Mathematical reasoning is missing from the typical U.S. math lesson, and our content is less challenging than that of many other countries. It is also clear that U.S. students fare poorly trying to solve multistep word problems. They fare better on computation problems with no context. To reach the U.S. goal

[2] The TIMSS Case Study on Japan indicates that a relatively small proportion of elementary students participate in the after-school juku schools and that they are more likely to be engaged in recreational or arts courses there. It is in eighth grade that more students begin attending for academic content to prepare for high school entrance exams at the end of grade 9.

[3] *Pursuing Excellence: A study of U.S. Eighth-Grade Mathematics and Science Teaching, Learning, Curriculum, and Achievement in International Context* (1996). U.S. Department of Education, National Center for Education Statistics.

of being first in the world in mathematics, we need to improve the balance of the curriculum devoted to basic, foundational skills and to more advanced and complex skills so that increasing numbers of students are prepared for the study of higher mathematics. But clearly, in this rebalancing, we must not lose a necessary focus—the need for children to master the basics.

If we want to raise math achievement, teachers must understand the instructional practices that TIMSS found in strong math lessons. To help do this we must ensure that future and current teachers alike gain a level of mathematical knowledge that many, through no fault of their own, do not now have. Without that knowledge, it is difficult to successfully engage students in learning math concepts and procedures, mathematical problem solving, and mathematical reasoning.

How Do TIMSS Results Support AFT's Reform Agenda?

Goal	TIMSS Finding
1. Adopt rigorous academic standards.	Our content level is below that of other countries. Most countries have nationally or state determined standards.
2. Adopt curriculum aligned to those standards.	U.S. curricula are unfocused and low-level. We teach more topics each year than 75 percent of TIMSS countries. U.S. teachers use mainly routine problems and tasks.
3. Eliminate out-of-field teaching assignments.	The concept of teaching out of field is unknown in most TIMSS countries. Teachers of math in other countries have been prepared to teach math.
4. Improve the quality of teacher preparation, including the level of content knowledge required. This may include greater knowledge of the content fields they teach and their most crucial ideas.	Teachers in high-achieving countries are required to pass rigorous subject-matter exams before being admitted to teacher training.
5. Align standards, curriculum, textbooks, and assessment.	The education ministries in many countries must approve textbooks. Some publishers purposely develop them to match the learning goals. Even when there is no central adoption, curriculum goals are clear and centrally decided, making it easier for publishers to produce books that are aligned with the goals.
6. Provide time for collaborative work, observation of good practice, and peer coaching.	The value of collaboration on lessons and opportunities to observe colleagues teach is clear in the practices of Japan.
7. Get rid of constant interruptions of lessons with which teachers are faced.	Interruptions in U.S. classrooms exceed those of other countries. International educators were amazed by the interruptions and could not understand why they were permitted.

For more information on TIMSS, contact:

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