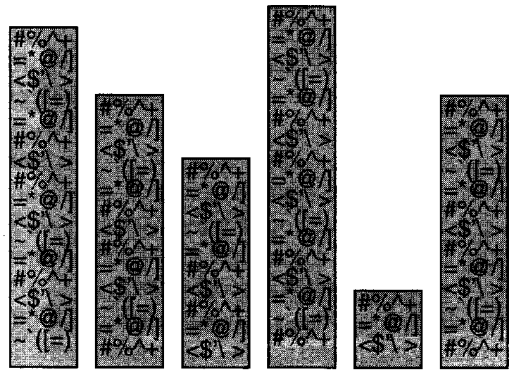
Message and Meaning:
The Third International Math and Science Study

by Barbara Bernstein



U.S. students must be challenged to work harder, and teachers and parents must drive the issue home.

In the fall of 1996, some early results were published from the Third International Mathematics and Science Study (TIMSS), the most comprehensive and rigorous international comparison of education ever undertaken. This study involved half a million students from forty-one developed and undeveloped countries at five different grade levels. The results published thus far show that the United States eighth-graders scored below the international average in mathematics, outperforming the students in only seven other nations. (Our students did about the same as students in thirteen countries and were outperformed by students in twenty countries.) And in science, the United States students did only slightly better. This paper will concentrate on mathematics education, for that is where the greatest problem lies. It will take time to digest all of the findings, but one thing is clear—the study sends a dynamic message on the poverty of our curriculum and our educational system.

The study begins with a striking demonstration of how far behind we are. The average achievement difference between the United States seventh- and eighth-graders was twenty-four points on the mathematics test, a point spread which can serve as a sort of "unit of measure." The difference between the eighth-graders in the United States and Singapore, the top-scoring country, was 143 points. This means that the difference in how much mathematics the eighth-graders in those two countries know is six times the difference between what U.S. seventh- and eighth-graders know! Here is still another way to look at the discrepancy between countries. In mathematics, our eighth-graders who score at the ninety-fifth percentile do approximately the same as average (fiftieth percentile) eighth-graders in Singapore.

It may be worth noting that we are a large country and our own scores are enormously diverse. If we break down scores by state, the average mathematics scores in Iowa, North Dakota, and Minnesota were similar to top-scoring Taiwan and Korea. On the other hand, our students in Alabama, Louisiana, and Mississippi scored about the same as the lowest-

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scoring country, Jordan.

Overall, the United States has been found to have about the same standing on international studies for the past couple of decades despite our ongoing efforts to improve education (i.e., IEA First and Second International Mathematics Studies of the 1960s and the 1980s, and the math portion of the International Assessment of Educational Progress test in the early 1990s). The current study attempted a thorough analysis of classroom lessons as well as the lifestyles of students and teachers in some sample countries to account for the international differences. First, some commonly held assumptions about reasons for our poor performance were disproved.

Apparently we are not doing poorly due to the amount of time spent in class (as has been previously suggested). United States eighth-graders spend more hours per year in math class than eighth-graders do in Japan and Germany, for example. And the amount of homework assigned does not appear to be a factor. U.S. students get more homework than the German and Japanese students, yet those countries outscore us. Nor is television watching the culprit. Eighth-graders in all three countries spend about the same amount of time watching television or videos.

But the intensive investigation that was conducted as part of the TIMS Study *was* uniquely effective in shedding light on the problem. In the three sample countries (United States, Japan, and Germany), lectures were videotaped and translated into English. All references to culture were removed, and then the lectures were analyzed in detail by mathematics experts. It was generally determined that the United States mathematics curriculum is not as advanced as that in Germany and Japan. In particular, the experts coded the content of the lessons according to whether the students were practicing a routine procedure (e.g., basic calculations), or doing work that requires a deeper level of thinking and understanding. In the United States, students practiced routine procedures *ninety-six percent* of the time they spent in their seats. In Japan only *forty-one percent* of the time was spent this way. At the other extreme, students were asked to invent new solutions, proofs, or procedures on their own using high-level reasoning in *less than one percent* of the United States lessons. However, this higher level of mathematical exercise occupied *fully forty-four percent* of the lesson time in Japan, the third highest scoring country. (Japan was beaten only by Singapore and South Korea.)

Furthermore, in our country, mathematics concepts were generally just stated by the classroom teacher. However, concepts were developed in some depth in the Japanese and German classrooms,. For example, suppose students were finding the length of the hypotenuse in a right triangle by using the Pythagorean theorem. The Pythagorean theorem states that $A^2 + B^2 = C^2$. In the United States this formula would generally just be given. In Germany and Japan, teachers usually proved, derived, or displayed in detail the meaning of such a formula. Note that these findings do not mean that there are no lessons of high-quality mathematical reasoning anywhere in our country. They *do* mean that such lessons are rare.

I think it is important to caution readers not to misapply the message of this study. The message is not that rote practice is bad. Although deeper conceptual understanding is needed, there is a role for rote practice. Even in high-scoring Japan, almost half the class time

was spent on drills. The point is that either type of work without the other yields an inadequate education.

As one might expect, since education reform has been in the air for quite some time, the professional organizations of math teachers have long been making efforts to improve standards. In 1989 the National Council of Teachers of Mathematics wrote *Curriculum and Evaluation Standards* and in 1991 *Professional Standards for Teaching Mathematics,* which basically encouraged teachers to aim for conceptual understanding as well as facts and skills. Interestingly enough, the Japanese lessons generally resembled the recommendations of the National Council of Teachers of Mathematics, while the United States lessons did not.

This leads to what could be considered the most subtle and impressive finding of all: the discrepancy between the teachers' perceptions of what they were doing and what the TIMS Study found they were actually doing. Ninety-five percent of the United States math teachers indicated that they were aware of the current ideas on teaching and learning mathematics—such as the standards in the documents by the National Council of Teachers of Mathematics. When the teachers finned in the study were asked to evaluate whether their videotaped lessons were in accord with current ideas about teaching mathematics, the results were striking. Almost seventy-five percent of the teachers said that their lessons were consistent with those standards either "a lot" or "a fair amount." This was not the case according to the experts who viewed those videos.

This issue prompted the researchers to ask teachers which math education reform ideas they were applying in their videotaped lessons. More than eighty percent of the teachers mentioned something other than a focus on mathematical thinking, which is really the central message of the reform movement. For example, cooperative learning or hands-on experiences were mentioned a lot. But as the TIMS Study points out, these techniques can be used "with or without engaging students in real mathematical thinking." Indeed the videotape study did show many examples of these techniques being used, but *without* "high-quality mathematics content." Hence teachers were focusing on side issues and did not realize they were missing the main point.

Furthermore, the American math lessons were "strikingly consistent," according to Professor James Stigler of UCLA, who coordinated the videotaping. They reflected an emphasis on rote procedures with drills designed to enable students to feel successful and receive praise. Our teachers were found to be "very uncomfortable" watching students struggle with a problem. They rushed over to show a student how to solve a problem rather than watch the student work through his or her confusion. In countries where students learn more mathematics, teachers were willing to let the students struggle, make mistakes, and find their way. I believe that our problems with education will not go away unless teachers as well as parents become comfortable watching students struggle a little with their work.

Another factor in our students' poor performance is subtle but important: a written curriculum can be misleading. It is how the curriculum is covered that tells the story. I think this is best illustrated with an example from my own tutoring. Last summer I gave several review sessions to a friend's seventh-grade son who was having trouble in math. I mixed together problems that involved the four operations with whole numbers and fractions, and required a knowledge of the order of operations—all material he had covered in school. It was tough for him because he had to remember what to do first and next, when to get a common denominator, and when to keep the denominator the same in the answer as opposed to changing it (as in addition versus the multiplication of fractions).

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When the summer was over, I had to stop tutoring him, but his mother found someone else to continue the work. She later told me the new teacher covered one kind of problem at a time, implying that

her son was more comfortable with this approach. That is, one day there were twenty problems on the addition of fractions, the next tutoring session was devoted to the multiplication of fractions, etc. This is much less difficult because the student merely has to keep repeating the same process. It can be done without a high level of understanding. The key here is that in both cases the "curriculum!" (in the sense of what is covered) is identical. Yet in one approach, students have to understand what they are doing to finish the assignments; in the other approach students can do the assignments with very little thinking and learning.

The TIMS Study videotapes demonstrated that our classroom teachers are very anxious to make math lessons pleasant, so they may understandably opt for the less stressful teaching approach. But there is no doubt that in a given amount of work time, students learn far and away more mathematics when different problems are mixed together even though the work is more stressful. This kind of subtlety may explain why students test poorly even though an earnest effort is made in class to cover a substantial curriculum Basically, the teachers' outlook on the rigor of their teaching approach is colored by their desire to make the work pleasant and for students to be easily successful.

But in fairness to teachers, it is also important that we recognize that a teacher's approach in the classroom is also partly determined by students' willingness to work, the parents' attitudes, and even cultural norms. These all form a system and influence each other. The educational system does not exist in a vacuum; our social milieu substantially affects how teachers do their jobs.

For example, I think we all recognize that teachers generally teach to the level that the students' abilities permit. Teachers are also able to teach only to the level of effort that students will expend. Effort comes in different forms. It can be the amount of time put in, which the TIMS Study demonstrated is no less here than in countries that score very high. There is also the matter of mental effort expended. Students may spend time solving problems only if they are not too challenging and do not tax them too much. Likewise teachers or parents may be comfortable only asking students to do low-stress work. Sometimes parents or students object if a teacher attempts a challenging curriculum, and vice versa.

I have seen this many times in my own dealings with the schools. I once attended a school meeting where I suggested that the students be required to read more. I was told that the teachers felt they could not possibly assign more reading because the students just would not do it. (The students were in a program for the gifted but they read very little.) Unfortunately, a commonly held belief today is that students should not see a lot of corrections on their papers that would threaten their self-esteem. As a parent myself I have asked teachers to correct my children's spelling and grammar when they handed in essays. I was told many times this would not be done for fear of discouraging the student. Similarly, I recently noticed a *Washington Post* letter to the editor on the subject of education. An English teacher wrote in to say that she tries to correct spelling but gets criticism from some parents when she does. The parents feel she should not make these corrections because the student's ideas are what count. Clearly if one partner in the education dance is willing to challenge students, another often is not.

There is still another point regarding the curriculum that may account for some of our difficulties. It is that understanding is not an all-or-nothing phenomenon. One does not simply understand or fail to understand how to add fractions, for example. Students (and adults too) understand by matters of degree. And I believe that the measure of understanding in mathematics is how difficult a problem the student can perform. A student may be able to solve the problem 1/2 + 1/3 by converting to sixths and then performing the necessary addition. However, if a student can do that problem but cannot solve 1/27 + 4/15, then he does not understand the material fully. Teachers, parents, and the students themselves can understandably be fooled by this scenario into thinking that the stu-

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dent understands but is "tripped up" by the mechanical calculations. Furthermore, recalling how to solve a challenging problem a few weeks later (when the class is studying a different unit) shows that the understanding is solid. We must not be seduced into believing that it is good enough to be able to add 1/3 + 1/2, as though that proves conceptual grasp and anything beyond that is gravy. This is not true precisely because understanding is incremental not all-or-nothing.

Another factor that would help is certainty that the teachers' own education meets reasonable standards of intellectual rigor. I have been dismayed to occasionally see papers come home with my children that show basic efforts in spelling and grammar on the teachers' part. One measure that would guarantee a minimum level of proficiency for all teachers is this: Have teacher applicants write an essay and take a basic math test when they apply for the job, and perhaps a simple exam in their content area. The work should be done in the office where they apply—not taken home where applicants would have the advantage of "spell-check" and reference books. This way, we would know before hiring whether someone is lacking basic skills.

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It has been suggested that our teachers have weaker educational backgrounds than teachers in other countries which might explain some of these observations. However, the TIMS Study found that United States teachers have more degrees and credentials than teachers in all but a few of the other countries studied. Almost half of the teachers of our eighth-grade students had master's degrees, a proportion exceeded by only four other countries in the study. By contrast, in Japan, few teachers had more than a bachelor's degree with teacher training. Obviously though, formal degrees in the field of education do not necessarily correlate with skill in the art of instructing students.

Interestingly, the TIMS Study did find important differences in how teachers in the three sample countries are trained. Teachers in Japan and Germany have a longer period of being mentored in programs much like apprenticeships. Teachers in Germany must spend two years in student teaching. In Japan new teachers undergo intensive training during the first year on the job. They continue to get guidance from more experienced teachers in subsequent years. The United States teachers spend only twelve weeks or less in student teaching. Then U.S. teachers begin work with no more structured oversight than veteran teachers get. It might be a good idea to require that our teachers periodically observe how other teachers covering the same material conduct class. Observations could be made of teachers who are considered particularly strong. Teachers could only benefit from this additional training.

Many measures to improve math performance are suggested by the findings of the TIMS Study. The main finding in short, is this: In America, teachers explain a procedure and students practice it with inadequate conceptual understanding. Advanced ideas are covered only superficially. The videotape study documented the teachers' commitment to producing successful and praiseworthy students. It is only natural that this might influence teachers to keep lessons simple and low in stress while making optimistic assessments of how their students are doing. But obviously this well-intended impulse does not help students in the long run. We can see from the example of other countries that students are capable of learning much more. I know someone who came here from China with her extended family. All of the children in her family who took the SAT got either 800 or nearly 800 on the math portion. My friend explained, "They all said the test was so easy." Doesn't that say it all? eH

International Association for the Evaluation of Educational Achievement, *Mathematics Achievement in the Middle School Years: LEA's Third International Mathematics and Science Study* (TIMSS) (Chestnut Hill, Mass.: TIMSS International Study Center, Boston College), November 1996.

Pat Wingert, "The Sum of Mediocrity," *Newsweek*, 2 December 1996, 96.

Rene Sanchez and Robert O'Harrow, Jr., "U.S. Struggles to Solve Its Math Problem," *Washington Post*, 23 January 1997, A1, A11.