A world of difference

Classrooms abroad provide lessons in teaching math and science

BY JAMES HIEBERT AND JAMES W. STIGLER

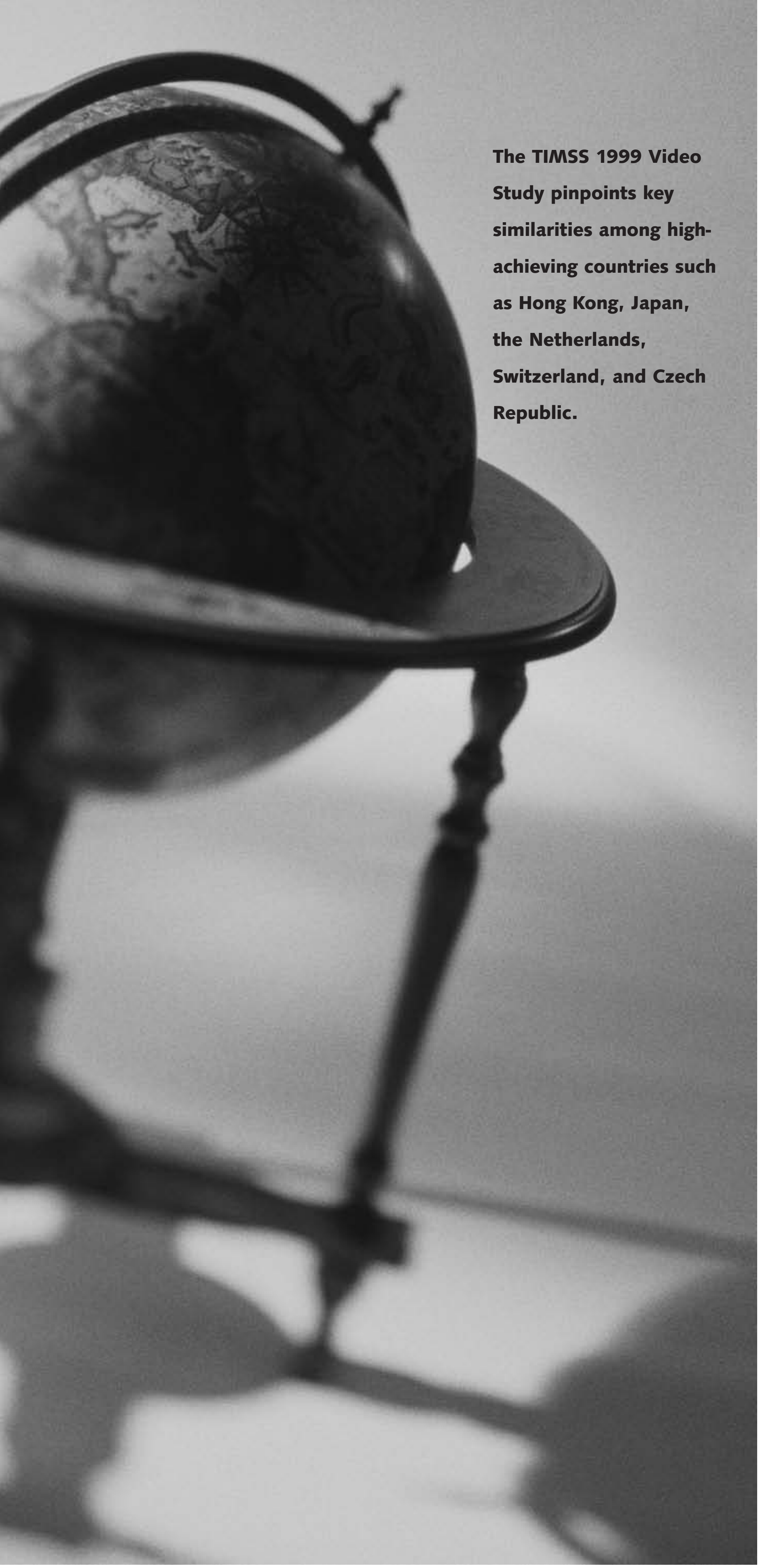
Improving classroom teaching is hard work. The literature is filled with stories of good intentions to change teaching followed by a disappointing return to traditional methods of practice. While learning how difficult it is for teachers to change the way they teach, educators also have learned that change is enabled when teachers have a clear target for change.

INTERNATIONAL COMPARISONS

One target for change is suggested by findings from the Third International Mathematics and Science Study (TIMSS) 1999 Video Study: Students need regular opportunities to explore mathematical relationships to develop high levels of understanding, in addition to developing skills. The reason this change is needed begins with the fact that both domestic and international assessments of achievement show that U.S. students are learning less mathematics than they could, and learning it less deeply (Silver & Kenney, 2000; Gonzales, et al., 2000). But why students are underachieving is a matter of heated debate. One hypothesis is that classroom instruction underem-

JAMES HIEBERT is the Robert J. Barkley professor in the School of Education at the University of Delaware. You can contact him at the School of Education, 107A Willard Hall Education Building, Newark, DE 19716, (302) 831-1655, fax (302) 831-4110, e-mail: hiebert@udel.edu.

JAMES W. STIGLER is professor of psychology at UCLA, and founder and CEO of LessonLab. You can contact him at UCLA Psychology Department, Franz Hall, Los Angeles, CA 90095-1563, (310) 664-2301, e-mail: stigler@psych.ucla.edu.



The TIMSS 1999 Video Study pinpoints key similarities among high-achieving countries such as Hong Kong, Japan, the Netherlands, Switzerland, and Czech Republic.

phasizes basic skills. Another hypothesis, from an opposite point of view, is that instruction underemphasizes conceptual understanding. The debate between skills and understanding has a long history in U.S. education and, recently, has become a central issue in the math wars (for example, see Loveless, 2001; National Council of Teachers of Mathematics, 2000; Kilpatrick, Swafford, & Findell, 2001).

It was in the context of this debate that we launched the TIMSS 1999 Video Study, the largest and most ambitious international comparison of teaching conducted to date. Random, nationally representative samples of 8th-grade lessons in mathematics and science were videotaped in a number of countries in Asia and Europe that achieve well on international comparisons. Results from the mathematics sample in the video study were released in 2003 (Hiebert, et al., 2003a) and results from the science sample are planned for release in 2004 (Roth, et al., in press). We studied a number of dimensions of teaching, including the ways classrooms are organized in the different countries, the kinds of mathematics problems presented to students, and the ways problems are worked on during classroom lessons. Can these analyses of

The TIMSS 1999 Video Study is the largest and most ambitious international comparison of teaching.

high-achieving countries yield clues that might be relevant to the U.S. debate between skills and understanding?

Results from the study showed that high-achieving countries (Czech Republic, Hong Kong, Japan, Netherlands, Switzerland) teach 8th-grade mathematics in different ways (Hiebert, et al., 2003a). No single method of teaching appears to be necessary for high mathematics achievement. As one example, we saw a great deal of variation in the relative emphasis given in each country to problems designed to teach skills vs. problems designed to teach conceptual understanding — that is, problems that gave students opportunities to connect mathematical facts, ideas, and strategies. All countries spent some time on each type of problem, but the relative emphasis on conceptual problems varied from a high of 54% of the problems in Japan to a low of 13% in Hong Kong. (The U.S. fell in between these two, with 17%.) Japan and Hong Kong were the highest achievers in our sample, yet they were at opposite ends of the spectrum on this dimension.

Compared with their international peers, 8th graders in the United States almost never got the chance (less than 1% of the time) to explore and discuss mathematical relationships while solving these problems.

A closer look revealed, however, that beneath the variability, there was a fascinating similarity among the high-achieving countries, one that distinguished them from the United States (Hiebert, et al., 2003b; Stigler & Hiebert, 2004). Although teachers in the United States presented problems of both types (practicing skills vs. "making connections"), they did something different than their international colleagues when working on the conceptual problems with students. For these problems, they almost always stepped in and did the work for the students or ignored the conceptual aspect of the problem when discussing it. Teachers in high-achieving countries differed considerably from each other in how many problems of this kind they presented, but when such problems were presented, they implemented a similar percentage of problems (about 50%) in such a way that students studied the connections or relationships embedded in the problems. Compared with their international peers, 8th graders in the United States almost never got the chance (less than 1% of the time) to explore and discuss mathematical relationships while solving these problems. (See example in the box above.)

Teachers in high-achieving countries implemented at least some of these problems in the first way rather than the second way; teachers in the United States almost never did.

The significance of this finding cannot be overestimated. It says, first, that U.S. students (at least in 8th grade) are spending almost all of their time practicing skills. This is consistent with many reports from the past about the nature of mathematics teaching in this country (Fey, 1979). Teaching in the typical classroom has not changed much. The debate about how much emphasis to place on skills vs. understanding has not created opportunities for students in typical U.S. classrooms to develop both skills and understanding. We share the view with others (Kilpatrick, Swafford, & Findell, 2001) that both skills and understanding are critical. If educators agree that a balance is important, and if they take seriously the results from the TIMSS Video Study, then efforts to improve should focus on ensuring that students have some opportunities to solve challenging problems that require them to construct mathematical relationships — to develop conceptual understanding. Currently, students in typical 8th-grade mathematics classrooms are working only on skills.

A second consequence of this finding is that curriculum reform is

Two teaching approaches to one concept

Imagine the following problem:

"Find a pattern for the sum of the interior angles of a polygon."

This is a common problem in many 8th-grade curricula, and the intent is for students to explore the relationships among the measures of angles in figures with different numbers of sides and detect a pattern in the ways that the sums can be calculated.

Method 1

Teachers could implement the problem by asking students to measure the angles in various triangles, quadrilaterals, and pentagons, finding the results of 180 degrees, 360 degrees, and 540 degrees, respectively. Then they might ask students what patterns they see, whether they could predict the sum of the interior angles of six-sided figures, and, eventually, whether they could develop a rule for the sum of angles if one knew the number of sides.

Method 2

Alternatively, teachers could simply say, "There is an easy way to calculate the sum of the interior angles of a polygon — just count the number of sides, subtract two, and multiply by 180: Sum = 180(n-2)."

not enough. The percentage of mathematics problems presented in U.S. classrooms that aimed to engage students in more ambitious and creative conceptual activity was similar to several other high-achieving countries. The difference lay in how teachers implemented the problems with students. This is an issue of teaching. This is not changed by rewriting the curriculum.

In summary, the findings of the TIMSS 1999 Video Study show that different high-achieving countries have chosen different levels of emphasis with regard to skills vs. understanding. These results suggest that the exact amount of time spent on these learning goals is not the critical factor. Rather, the results suggest that some time should be devoted to practicing skills and some time devoted to developing understanding. U.S. teachers already provide practice on skills. This now needs to be balanced with solving challenging problems and discussing the relationships that can be constructed among the mathematical facts, procedures, and ideas. When working on these problems, teachers must learn how to avoid stepping in and giving the answers, and instead provide students with opportunities to think more deeply about mathematical concepts and then discuss these concepts or relationships with the students. How can teachers be supported to make this change?

LESSONS FROM RESEARCH

Just as educators are learning more about the features of teaching that should be targeted for improvement, and just as they are learning more about why teaching is so difficult to change, they also are learning more about professional development strategies that can support change. For starters, it is helpful to think about teaching as a cultural activity rather than as something one learns to do by studying it in school (Gallimore, 1996). That is, most teachers learn to teach by growing up in a culture, watching their own teachers teach, and then adapting these methods for their own practice. Changing teaching means changing the culture of teaching, not distributing more recommendations or holding more workshops.

Teaching can only change the way cultures change: gradually, steadily, over time as small changes are made in the daily and weekly routines of teaching. Consider the daily routines of most teachers. Lessons are planned (sometimes quickly, by identifying a sequence of activities), then implemented, then assessed (sometimes by watching students' reactions during the lesson, listening to students and questioning them informally, and collecting student work), and then reflected on (sometimes quickly, by making mental notes of what worked well and what didn't, who acted up, and so on). By studying how many teachers changed their teaching, we have learned that to begin the process of change, these phases of teaching must be slowed down and examined more carefully. Teachers must find ways to spend a little more time each week planning how to implement a few mathematics problems to engage students in thinking about key mathematical relationships suggested by the problem. And they must reflect, in more detail, on how students responded to these opportunities so they can improve the effectiveness with which such problems can be implemented the following day or week. Over time, these kinds of small, targeted changes in teachers' weekly routines change the culture of teaching — for the individual teacher, for the group of teachers who engage in this kind of work together, and, eventually, for the school.

> **How to change teaching**
>
> Three tips to change teaching to improve student achievement:
>
> 1. Shift priorities to spend some time daily or weekly studying teaching practices; focus on planning lessons and then reflecting on their effectiveness.
> 2. Provide teachers vivid examples of alternative teaching methods.
> 3. Have teachers learn to analyze students' work and understand their thinking to see how to adjust and improve their teaching methods.

Of course, changing a culture is not simple or easy. How do teachers go about the business of changing their weekly or daily routines, and what, exactly, do they do when they study teaching? We offer three suggestions.

> **Educators often underestimate how much learning is required to teach in a different way and how much time this takes.**

First, finding time in the daily or weekly schedule is a key enabler. Educators often underestimate how much learning is required to teach in a different way (Cohen & Barnes, 1993) and how much time this takes. But for teachers, extra time is hard to find. A solution often is reallocating existing time rather than trying to find new time. Time spent in department meetings, grade-level meetings, and one-time workshops can be reallocated to time for studying and improving teaching in a systematic and continuing way. This shift will require changing priorities and creative scheduling, but it is the kind of commitment essential for instituting the regular, weekly collaborative study needed to improve teaching in a lasting way.

Second, teachers must be provided with vivid examples that illustrate alternative ways of teaching. If the goal is to learn how to work on mathematics problems so students can make connections to understand concepts and procedures, then teachers need images of what this kind of teaching looks like. Analyzing videos of teaching in detail and focusing intensely on the ways different teachers implement these kinds of problems can be rich learning opportunities. Studying the ways teachers present problems to students, asking students to develop problem-solving methods, comparing solution methods, looking for patterns, and comparing one problem to others provides a range of techniques that teachers can consider as they plan their own lessons. Finding useful videos is a challenge. The set of public-use videos collected as part of the TIMSS Video Study is one source. Samples of teaching do not need to show exemplary practice to be useful (Stigler & Hiebert, 1999). Examining everyday teaching, with its missed opportunities, also can be an important learning activity. Eventually, teachers can analyze videos of their own teaching, an essential experience for improving their practice.

When teachers recognize that knowledge for improvement is something they can generate, rather than something that must be handed to them by so-called experts, they are on a new professional trajectory.

Third, teachers must have opportunities to study students' responses to the changes teachers make in the classroom. If the goal is to learn how to implement mathematics problems so students can make connections to understand the concepts and procedures, then the critical information is whether, and to what degree, students achieve this goal. This requires information from students — how they solved the problem, how they explained their thinking, what errors they made, and so on. Learning to analyze student work and to make inferences about students' thinking can lead to significant changes in teachers' practices (Kazemi & Franke, in press).

Notice that the suggestions we offer for changing the culture of teaching to enable targeted changes in teaching practice assume many of the features recommended numerous times in the professional development literature (Darling-Hammond & Sykes, 1999; Sparks & Loucks-Horsley, 1990): situated in teachers' practice, connected to the curriculum, focused on clear student learning goals and student thinking, and continuing over time. There is growing evidence that these features are critical. But, to change cultures, educators need to appreciate the importance of examining the routines of teaching, slowing them down, and changing them, even a little. Developing a routine of planning for teaching and reflecting on teaching, with a particular learning goal in mind, can gradually but steadily change the culture of teaching.

CONCLUDING THOUGHTS

Everyone, including teachers, learns from everyday experiences, but usually this learning is haphazard and fleeting. Professional developers and teachers can do better than this. They can learn from carefully planned experiences. By planning to learn, teachers maximize the benefits they reap from studying their practice. This is exactly the kind of cultural change we envision. Begin with professional daily and weekly routines that are familiar — planning to teach, implementing lessons, assessing students' learning, and reflecting on how things went. Now slow down these routines and change them, even a little, by devoting more thought to how mathematics problems can be worked on with students and by studying more carefully the effects of these changes on students' thinking and understanding. Plan to learn about teaching by studying targeted instructional activities and their effects.

These ideas can be tied together by saying that teaching should have an "experiment" built in (Hiebert, Morris, & Glass, 2003). Planning to learn from teaching means setting clear learning goals (for the students and for the teacher), planning instructional activities hypothesized to achieve the learning goals for students, collecting data from students about how well the goals were achieved, and interpreting the data to revise the hypotheses and improve the lesson next time. These processes simulate experiments conducted in other settings and represent systematic, continuing, and increasingly rich professional development activities for teachers.

The payoff for teachers is the knowledge they acquire to guide improvements in their own practice. When teachers recognize that knowledge for improvement is something they can generate, rather than something that must be handed to them by so-called experts, they are on a new professional trajectory (Franke, Carpenter, Fennema, Ansell, & Behrend, 1998). They are on the way to building a true profession of teaching, a profession in which members take responsibility for steady and lasting improvement. They are building a new culture of teaching.

REFERENCES

Cohen, D.K. & Barnes, C.A. (1993). Pedagogy and policy. In D.K. Cohen, M.W. McLaughlin, & J.E. Talbert (Eds.), *Teaching for understanding: Challenges for policy and practice* (pp. 207-239). San Francisco: Jossey-Bass.

Darling-Hammond, L. & Sykes, G. (Eds.). (1999). *Teaching as the learning profession: Handbook of policy and practice.* San Francisco: Jossey-Bass.

Fey, J.T. (1979). Mathematics teaching today: Perspective from three national surveys. *Arithmetic Teacher, 27*(2), 10-14.

Franke, M.L., Carpenter, T.P., Fennema, E., Ansell, E., & Behrend, J. (1998). Understanding teachers' self-sustaining, generative change in the context of professional development. *Teaching and Teacher Education, 14,* 67-80.

Gallimore, R.G. (1996). Classrooms are just another cultural activity. In D.L. Speece & B.K. Keough (Eds.), *Research on classroom ecologies: Implications for inclusion of children with learning disabilities* (pp. 229-250). Mahwah, NJ: Lawrence Erlbaum Associates.

Gonzales, P., Calsyn, C., Jocelyn, L., Mak, K., Kastberg, D., Arafeh, S., et al. (2000). *Pursuing excellence: Comparisons of international eighth-grade mathematics and science achievement from a U.S. perspective, 1995 and 1999.* (NCES 2001-028). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Hiebert, J., Gallimore, R., Garnier, H., Givvin, K.B., Hollingsworth, H., Jacobs, J., et al. (2003a). *Teaching mathematics in seven countries: Results from the TIMSS 1999 video study.* (NCES 2003-013). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Hiebert, J., Gallimore, R., Garnier, H., Givvin, K.B., Hollingsworth, H., Jacobs, J., et al. (2003b, June). Understanding and improving mathematics teaching: Highlights from the TIMSS 1999 Video Study. *Phi Delta Kappan, 84*(10), 768-775.

Hiebert, J., Morris, A.K., & Glass, B. (2003, September). Learning to learn to teach: An "experiment" model for teaching and teacher preparation in mathematics. *Journal of Mathematics Teacher Education, 6*(3), 201-222.

Kazemi, E. & Franke, M.L. (in press). Teacher learning in mathematics: Using student work to promote collective inquiry. *Journal of Mathematics Teacher Education.*

Kilpatrick, J., Swafford, J., & Findell, B. (Eds.). (2001). *Adding it up: Helping children learn mathematics.* Washington, DC: National Academy Press.

Loveless, T. (Ed.). (2001). *The great curriculum debate: How should we teach reading and math?* Washington, DC: Brookings Institution.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics.* Reston, VA: Author.

Roth, K.J., Druker, S.L., Garnier, H., Lemmens, M., Kawanaka, T., Rasmussen, D., et al. (in press). *Teaching science in five countries: Results from the TIMSS 1999 video study.* Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Silver, E.A. & Kenney, P.A. (Eds.). (2000). *Results from the seventh mathematics assessment of the National Assessment of Educational Progress.* Reston, VA: National Council of Teachers of Mathematics.

Sparks, D. & Loucks-Horsley, S. (1990). Models of staff development. In W.R. Houston (Ed.), *Handbook of research on teacher education.* New York: Macmillan.

Stigler, J.W. & Hiebert, J. (1999). *The teaching gap: Best ideas from the world's teachers for improving education in the classroom.* New York: Free Press.

Stigler, J.W. & Hiebert, J. (2004, February). Improving mathematics teaching. *Educational Leadership, 61*(5), 12-17.

Samples of teaching do not need to show exemplary practice to be useful.