THIRD INTERNATIONAL MATHEMATICS AND SCIENCE STUDY (TIMSS) AND THE NATURE OF COLLEGE COURSES

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The TIMSS report leads to some strong conclusions concerning the effectiveness of various approaches for teaching mathematics and science in grades K-8. This presentation will focus on a description of the findings of TIMSS concerning effective teaching. Although the TIMSS study and its findings relate directly to teaching prior to college, the findings do have a lot to say about effective teaching at the college level. At the very least, they describe the type of teaching and learning that future teachers must experience if they are to bring about this type of learning in their own courses.

The Third International Mathematics and Science Study (TIMSS) is the most comprehensive international education comparison ever undertaken. During 1995, data were collected from a half-million students in 41 countries. The TIMSS was designed to accurately compare achievement in science and mathematics across the nations that participated in the study. Student tests, questionnaires, videotapes of teaching, and curriculum materials were analyzed. The entire assessment process was established and rigorously scrutinized by an international review committee to ensure the validity and reliability of the study [1, 2, 3, 4, 5].

The TIMSS is only one study, but balanced with findings from other research it can provide insight into teaching and learning. This article will summarize the findings from the multiple TIMSS reports and suggest implications for college level teaching in science, mathematics, and education courses.

Achievement

The TIMSS achievement data show that U.S. student performance, relative to other countries, decreases in mathematics and science as students progress through school (see Figure 1, following page). In addition, U.S. students score better in science than mathematics at all grade levels.

- In fourth grade, U.S. students score among the highest nations in science and above the international average in mathematics.

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- In eighth grade, U.S. students score slightly above average in science and slightly below average in mathematics.
- By twelfth grade, U.S. students are among the lowest scoring nations in both science and mathematics.

	Grade 4 n=26	Grade 8 n=41	Grade 12 n=21
Science international average	above	above	below
Mathematics international average	above	below	below

n=number of countries in the study

Figure 1. TIMSS U.S. Achievement for Grades 4, 8, and 12.

Each test assessed multiple content areas within mathematics and science. In mathematics, the content areas with greatest achievement are data analysis and lowest achievement are measurement and geometry (see Figure 2, below).

	Grade 4	Grade 8	Grade 12
Above	data analysis geometry patterns numbers		
Average	fractions	data analysis fractions algebra	(AP calculus)
—international average—			
	measurement	proportionality	(calculus & AP calculus)*
Below		geometry measurement	general knowledge advanced mathematics numbers/equations calculus geometry

* (U.S. Advanced Placement calculus and calculus students compared to other advanced mathematics students)

Figure 2. U. S. achievement on mathematics content areas.

In science content areas students score highest on environmental science and have the greatest difficulty with the physical sciences (see Figure 3, below).

	Grade 4	Grade 8	Grade 12
Above	environmental science earth science life science physical science	environmental science	
Average ----*international average*----	 -------------------	life science earth science chemistry physics -------------------	 -------------------
Below			general knowledge physics heat, modern physics, waves, mechanics, electricity/magnetism

Figure 3. U.S. achievement on science content areas.

Teachers

There are differences in the structure of the teachers' school day and the training they receive.

- Japanese teachers have more time scheduled for planning during the school day than do U.S. teachers, consequently they have more students in each class to teach.
- Teachers entering the profession in Japan and Germany participate in a long-term apprenticeship program.
- U.S. teachers tend to have more college education than teachers in other countries.

Student characteristics

Initial investigation of the contextual factors in students' lives reveals little relationship to student performance in science and mathematics especially at the fourth and eighth grade levels. The study indicates that U.S. students in grade 12:

- Watch as much TV (1.7 hours per day) as students in other nations,
- Work more at paid jobs outside the home (61% compared to 28% international*ly) and* work longer hours per day (3.1 hours compared to 1.2 hours),

- Take less mathematics and science with many U.S. states requiring only 2-3 years of mathematics and 2 years of science in the four years of high school, and
- Report doing less homework than students in other countries.

U.S. curriculum

The U.S. does not have a national curriculum, which is unlike most other TIMSS countries. When compared to curriculum in other countries, the U.S. curriculum:

- Lacks focus,
- Canvases more topics in less depth (often described as a mile wide and an inch deep), and
- Contains are less advanced topics.

Delivery of instruction

The videotape study of classroom instruction includes only grade eight mathematics teachers from the U.S., Japan, and Germany. The videotapes reveal differences in the structure and delivery of lessons, kind of mathematics taught, kind of thinking students are engaged in during lessons, and teachers' view of reform. Japanese students score higher in achievement on the TIMSS than do students from the U.S. and Germany. U.S. and German students' scores are not significantly different.

Structure and delivery of lessons. In the U.S. and Germany, instruction is primarily based on problem solving, whereas in Japan it is on understanding. In the U.S. and Germany, lessons focus on developing skills and progress from an initial acquisition phase to an application phase. In Japan lessons focus on understanding the thinking behind concepts and progress from problem solving, to student sharing of solution methods, to jointly developing understanding of concepts.

U.S. lessons were less coherent as teachers switched between topics more often, covered more topics, provided few connections between topics, spent time on irrelevant diversions, and were more frequently interrupted by outside events. U.S. students spent more time in class reviewing or doing homework.

Kind of mathematics taught. U.S. lessons were less advanced when compared to the grade level that topics were taught in other countries, concepts were stated as opposed to being developed, and no lessons were assessed to be in the high quality category in a blind review of (low, medium, or high) lesson quality.

Kind of thinking students engaged in during lessons. U.S. and German students spent approximately 90% of their time practicing routine procedures compared to 41% for Japan. Japanese students spent 44% of their time inventing new solutions and engaging in conceptual thinking. Student-generated alternative solutions to problems were three times more likely to be part of Japanese lessons than U.S. or German lessons.

Teachers' view of reform. The *Curriculum and Evaluation Standards for School Mathematics* [6] and the *Professional Standards for Teaching Mathematics* [7] outline the National Council of Teachers of Mathematics recommendations on how to teach mathematics. Japanese teachers appear to be teaching more in line with these standards than U.S. teachers. When asked, U.S. teachers claim to be following the current thinking about effective mathematics teaching and learning. They justify their claims with more superficial reasons such as using manipulative and cooperative learning than with teaching for understanding. The videotape study suggests that having standards is insufficient for changing practices in the classroom and that developing a common understanding of what quality teaching looks like is needed.

Future TIMSS data

The TIMSS-R, which is a partial repeat of the 1995 study, is being conducted in the spring of 1999 for grade eight students. These are the same students who were in grade four in 1995 during the original TIMSS. In addition, a videotape study is being conducted for grade eight science teaching. As this information and further analysis of the original massive TIMSS data set become available, they will provide further insight into teaching and learning in the U.S. and in many other countries.

Implications for college courses

Many of the findings about curriculum and instruction in the TIMSS reports also apply to college teaching. Among the implications for college science and mathematics courses is the need for faculty to understand education research in order to provide effective instruction for all students. In order to accomplish this, professional development is needed for faculty to enable them to recognize the underlying principles of quality teaching and deliver this kind of instruction in their courses. Since pre-college teachers tend to teach in the same way they were taught, college faculty need to model effective teaching and learning in their courses for teachers. Since the faculty themselves probably did not participate in this kind of instruction when they were students, they will need long-term professional development and support in creating an environment in their own courses that maximizes student learning.

Therefore, collaboration among faculty in education, science, and mathematics is needed as they all learn about the TIMSS, other research findings on effective teaching, and seek to implement the findings in their own teaching. This will be a great challenge for college administrators to support, because teaching is not always valued and rewarded equally with research in science and mathematics. Establishing a long-term dialogue about teaching among faculty is key, as they grapple with the process of change and the discomforts and joys associated with change. Education faculty can facilitate this process for other faculty members by synthesizing the research about effective teaching, developing learning experiences to facilitate productive change, and supporting the change process for faculty in science and mathematics. The dialogue needs to produce and support quality teaching. In addition to critically analyzing research on effective instruction, a focus on conducting research on students' learning in their own classes may provide a basis for productive discussion and change.

If K-12 teachers are going to establish learning environments in their classrooms that foster students' understanding of science and mathematics, then they will need to participate in effective teaching and learning, collaborate with colleagues on a long-term basis to understand the underlying principles, and conduct research on their own classes to see what works with their students. Faculty can play a critical role in this process not only in helping them to understand science, mathematics, and education but also in helping teachers to conduct research on their teaching. ■

References

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