Much has been written in the past decade about the Third International Mathematics and Science Study (TIMSS), including the 1999 Video Study and the TIMSS 2003 test. The primary goals of the study were to evaluate mathematics achievement levels in several countries and to attempt to understand and explain the reasons for the differences (Stevenson 1998). The TIMSS case studies were compiled in Germany, Japan, and the United States and included videos of class sessions that were analyzed by an international team of researchers (TIMSS Video Mathematics Research Group 2003). The summaries of the research have been a basis for suggestions and changes in American classrooms. Specifically, the study clearly showed differences in the ways that teachers in Japan and in the United States conduct their classes that, in turn, may affect the academic achievement of their students. Several of the key findings will be discussed.

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in this article. Then, based on the research, questions will be presented and recommendations for teachers will be suggested concerning how U.S. mathematics teachers might rethink their methods of planning and teaching.

**BELIEFS ABOUT TEACHING MATHEMATICS**

A teacher’s philosophy of mathematics education serves as the basis for how he or she teaches mathematics. The results from the TIMSS study show that the teachers in Japan and the United States have differing beliefs. Japanese teachers view mathematics as a relationship among concepts, facts, and procedures; thus, they want their students to think about the relationships in a variety of ways. According to Stigler and Hiebert (1999), “These relationships are revealed by developing solution methods to problems, studying the methods, working toward increasingly efficient methods, and talking explicitly about the relationships of interest” (p. 89).

However, American teachers tend to see mathematics as a set of procedures and want their students to master those procedures (Stigler and Hiebert 1999). Clearly, Japanese and U.S. teachers have different beliefs about the nature of mathematics, which may explain the differences found in lesson planning, teacher behaviors, and mathematics achievement.

**HOW BELIEFS DRIVE LESSON PLANNING**

**The Structure of a Lesson**

The TIMSS videos exposed a major difference in the typical lesson structure of the two countries. In the United States, a typical lesson would follow these steps:

1. Review previous material (often by checking homework or conducting a warm-up activity).
2. Introduce new material (by presenting some sample problems and demonstrating how to solve them).
3. Assign seatwork by having the students individually practice problems similar to the ones demonstrated using the same methods.
4. Check the answers and assign more problems for homework.
5. Demonstrate another type of problem or use the remainder of class to do homework.

In Japan, however, the class would typically follow these steps:

1. Review the previous lesson (usually connected to the current lesson).
2. Present a new problem of the day, which students work on individually.
3. Place students into groups and discuss the problem further while observing the methods that students used.
4. Choose one or two students to present solutions to the class.
5. Lead the class in a discussion about the methods, while summarizing and elaborating on what students have presented.
6. Highlight and summarize the major points of the lesson and present a new problem in which students practice the methods discussed for solving the first problem (Stigler and Hiebert 1999).

**Planning the Lesson**

A common thread running through Japanese and U.S. lesson structure involves teachers presenting information to the students; however, the content is often presented differently. Overall, Japanese teachers develop concepts more often than U.S. teachers, who tend to state the necessary steps (Kawanaka, Stigler, and Hiebert 1999). U.S. teachers are more likely to direct student activity by giving and
emphasizing basic definitions, thus increasing the amount of stated procedures. For example, when students are incorrectly solving problems involving proportions, the teacher will read a definition from the textbook and explain again the steps needed to solve the problems (Cogan and Schmidt 1999). In fact, U.S. teachers gave twice as many definitions as Japanese teachers during a lesson (Stigler and Hiebert 1999). With such emphasis placed on memorizing definitions and procedures, U.S. teachers appear to be more focused on obtaining correct solutions. Japanese teachers are more focused on thinking about the relationships among concepts, facts, and procedures, so they will place more emphasis on thinking about the problems and solving methods than getting a solution quickly (Woodward and Ono 2004). When a problem is given in the Japanese classroom, the teacher does not generally begin to lecture, as is often seen in U.S. classrooms. Instead, the Japanese teachers allocate time for the students to explore solution methods by incorporating previous knowledge.

It is important to present information to students in a coherent manner. Lesson coherence is defined as “the connectedness or relatedness of the mathematics across the lesson” (Stigler and Hiebert 1999, p. 60). U.S. lessons were found to be less coherent because teachers switched topics frequently; changing and interrupting lessons hinders the student’s ability to understand mathematics and see the mathematical relationships among ideas, facts, and procedures. Since Japanese teachers want their students to see mathematical relationships, they specifically use certain problems that allow the students to understand the relationships between topics and ideas.

Complexity of Problems Posed in the Lesson
The beliefs and philosophies that teachers have about mathematics impacts the content of the lessons by affecting the complexity of problems the students explore. By and large, Japanese lessons were more complex because of the level of problems posed by the teachers (NCES 2003). Since many U.S. teachers want students to simply master skills, problems of low complexity are often posed in the classroom. Solving such problems that just focus on the skills needed instead of those that show relationships between mathematical concepts results in U.S. students mastering only those basic skills. The priority for Japanese teachers, however, is that students understand mathematical relationships; therefore, problems of higher complexity are assigned to give students the opportunity to investigate those relationships.

Similarly, the difference in lesson complexity can also be seen in the kind of seatwork that students are given. By and large, Japanese students spend more seatwork time inventing and thinking, whereas U.S. students spend more time mastering a procedure (Kawanaka, Stigler, and Hiebert 1999). When discussing a formula, teachers may show or ask students to prove that the formula is valid, and proofs are considered to be of high complexity. In the TIMSS Video Study, over half of the Japanese lessons included proofs; none were included in U.S. lessons (Kawanaka, Stigler, and Hiebert 1999). If U.S. students were to spend more time on reasoning and proof instead of strictly practicing procedures, then they might be able to better understand complex mathematical concepts.

Types of Questions Asked in the Classroom
Differences in beliefs about mathematics education can also be seen in the behaviors exhibited by classroom teachers. During a typical class session, teachers generally ask questions about the topic being discussed, but the types of questions being asked in U.S. classrooms tend to be less challenging than those asked in Japanese classrooms. The TIMSS Video Study divided questions into three categories: name/state, yes/no, and describe/explain. U.S. teachers asked more yes/no questions than those in Japan; Japanese teachers asked significantly more describe/explain questions (Kawanaka, Stigler, and Hiebert 1999). Included in the describe/explain category are questions that ask students to solve a problem in more than one way. When students are exposed to multiple ways to solve a problem, they can evaluate the benefits of each method as well as determine which methods are most beneficial in certain situations.

Dealing with Frustration in the Classroom
Students commonly encounter confusion or frustration with solving problems in mathematics classes; however, teachers in the two countries view this confusion differently. U.S. teachers tend to believe that students become frustrated or confused because skills taught earlier have not been mastered; therefore, it must mean that previous teachers have not done their jobs and need to step in and provide the necessary information. To reduce frustration, U.S. teachers present all the information required for solving problems (Stigler and Hiebert 1999). On the other hand, Japanese teachers believe that frustration and confusion are natural feelings that occur because students learn by struggling through how to solve problems. As Stigler and Hiebert (1999) pointed out, “constructing connections between methods and problems is thought to require time to explore and invent, to make mistakes, to reflect, and to receive the needed information at an appropriate time” (p. 91).
Addressing Mistakes in the Classroom

Another difference in teacher behaviors that surfaced in the TIMSS is how mistakes are handled during a lesson. Generally speaking, mistakes are tolerated in Japan; they indicate areas where students need to work harder because the culture emphasizes effort (U.S. Department of Education 2005). However, in U.S. classrooms, mistakes are viewed as being something bad, and teachers avoid discussing a student’s errors in class because they believe that it will hurt the student’s self-esteem. Japanese students do not seem to be bothered or embarrassed when their mistakes are addressed in class (Whitburn 1995). Likewise, Japanese teachers strongly believe that it is important for the students to learn from their mistakes so that they do not make the same errors again. Consequently, they accept all methods and solutions, even incorrect ones, and discuss them and use them as opportunities for learning (Schumer 1999). Conversely, the TIMSS videos show that U.S. teachers tend not to use student errors as learning tools.

ANALYZING YOUR OWN TEACHING PHILOSOPHY AND ACTIONS

Although it would be inaccurate to believe that “everything the Japanese are doing is correct” or that “all teachers in the United States need to change,” an analysis of the research from the TIMSS certainly raises some questions for teachers to consider. The following set of questions and comments are intended to serve as points of reflection and discussion, based on evidence from the TIMSS.

What is the goal of teaching mathematics? What am I really trying to accomplish in my classroom?

One item on the TIMSS teacher questionnaire asked teachers to identify the main idea that they wanted their students to learn from a videotaped lesson. In Japan, 73 percent of the teachers wanted their students to think about things in a new way, such as seeing different mathematical relationships. However, 61 percent of the U.S. teachers wanted their students to learn the skills needed to solve the problems (Stigler and Hiebert 1999).

A teacher’s beliefs will ultimately drive everything that is done in the mathematics classroom, including planning, selecting tasks, and teaching students. Teaching mathematics encompasses more than simply teaching students to master a list of skills. Educators need to step back from time to time and reconsider the purpose of teaching mathematics. It is too easy to get caught up in day-to-day activities and allow the district’s course of study or, worse yet, the contents of a textbook to become the be all and end all of teaching.

Does my lesson plan emphasize mathematical thinking and process, or is the goal to demonstrate procedures and obtain right answers?

The lesson plan serves as a window into the values of the classroom teacher. A lesson that is rich in mathematical processes, as opposed to procedural knowledge, reflects a philosophy that teaching mathematics is deeper than “showing students how to get the right answers” to a particular type of problem. Instead, the five Process Standards recommended by the NCTM—Problem Solving, Reasoning and Proof, Communication, Connections, and Representation—should permeate lessons taught in the classroom from early childhood through college. In the planning process, a teacher should consider how the lesson will not only enhance the content knowledge of the students but will also develop their mathematical processing skills. When reflecting on a lesson’s effectiveness, a teacher might ask such questions as, “How did this lesson enhance my students’ problem-solving skills?” and “In what ways did I promote oral and written communication of mathematical ideas in today’s lesson?”

Is there a place in my classroom for lecture? Do I balance my teaching strategies?

Analysis of Japanese and U.S. lessons seems to infer that a mathematics teacher should never “tell” students anything. But this is not consistent with the spirit of using an inquiry approach to teaching. Teachers can allow student thinking to drive a lesson while also interspersing anything from definitions to strategies—mathematical content knowledge—into the lesson. The key is not to allow these minilectures to dominate the teaching of mathematics. The adage that variety is the spice of life most certainly applies to the mathematics classroom.

Do I help my students find connections between big ideas in mathematics?

The TIMSS Video Study concluded that almost all of the Japanese lessons contained statements connecting one part of the lesson to another, whereas less than half of the U.S. lessons made connections (Stigler and Hiebert 1999). Of course, if the connections in a lesson are clear, then students will better understand mathematics and the
relationships among topics. Japanese teachers were six times more likely than U.S. teachers to have lesson parts that were interrelated (Stigler and Hiebert 1999). In the United States, teachers failed to use problems that make connections effectively; instead, the teacher stated the procedures or simply provided the students with the answers (Stigler and Hiebert 2004).

Often, the titles of chapters or even the names of standards are misinterpreted as barriers between content knowledge. For example, some view algebra as being inherently different and discrete from geometry and purposely divide the content of these topics into separate units. However, a middle school teacher who uses algebra tiles in the classroom can help students visualize problems involving polynomials as they connect the use of algebraic symbols to geometric interpretations of the problems. In this way, students recognize that mathematical concepts are connected to one another and begin to view mathematics as a cohesive set of processes and content.

**What type of seatwork do my students do?**

The TIMSS researchers categorized work that students engage in at their seats into three areas: practicing, applying, or inventing and thinking. When designing a lesson plan, it is important for mathematics teachers to ensure that students engage in all three areas. Japanese students do more inventing/thinking and proving in the classroom. The TIMSS research showed that the Japanese student spent an average of fifteen minutes on each mathematics problem they were given; however, U.S. students only spent an average of five minutes per problem (Stigler and Hiebert 1999). Students need more time to invent solutions and prove formulas than to simply answer practice questions. There is certainly a place for practicing skills, but unless lessons also involve opportunities to invent and think, the five mathematical processes tend to be ignored. When the vast majority of seatwork is focused on acquiring skills, students begin to view mathematics as the memorization of set procedures that can be practiced, rather than as a way of thinking and applying knowledge to new situations.

**What kinds of questions do I ask in my classes?**

Again, the TIMSS research used a three-part categorization process involving (1) “naming” or “stating [a definition, etc.],” (2) answering yes or no, or (3) describing and explaining. At times, it is appropriate to simply ask students to recall the definition, such as of a prime number. At other times, if mathematical thinking is being emphasized, students should also be asked to explain how they know that a particular number is prime, why a quadratic equation cannot have more than two solutions, and so on. A teacher who audiotapes his or her lesson should be able to identify the level of questions being asked. Questions that begin “Why do you think . . .” or “What would have happened if . . .” challenge students to think at higher levels than closed questions that begin “What is the answer to . . .” or “What are the factors of . . .”

**Do I tend to encourage students to find multiple ways to solve the same problem?**

The TIMSS research showed that Japanese teachers often ask students to solve a problem in as many ways as they can so that the class can compare the variety of methods available. In Japanese classrooms, almost half the lessons included students presenting alternative solutions. However, students in the United States rarely gave alternative methods, and instead teachers showed the class multiple approaches in about one of every five lessons (Stigler and Hiebert 1999).

Suppose, for example, that a student is given a simple equation to solve, such as $x + 5 = 12$. One solution method is to think about what number, when added to 5, will result in a sum of 12. Another method is to lay algebra tiles on a mat, with an $x$ and 5 unit tiles on one side and 12 unit tiles on the other, to determine that it would require 7 more units with which to replace the $x$ to balance the equation. Another student may put a thumb over the $x$ in the equation and recognize that the missing number is 7, since $7 + 5 = 12$. Still another student may subtract 5 from both sides of the equation to find the solution, the method most commonly taught in U.S. classrooms. All are legitimate ways to think through the solution. Comparing solution methods is a valuable classroom experience, because, with time, students will learn that some methods are more efficient or generalizable than others. But in the initial stages of the lesson, students should be encouraged to think creatively about different ways to solve such a problem. It is dangerous, indeed, when a teacher insists that students solve a type of problem “the way that I showed you,” rather than allowing students to discover methods that make sense to them.

**What do I do when students get frustrated or confused?**

The TIMMS research indicates that Japanese teachers do not give students...
the needed information at the first sign of frustration or confusion when solving a problem. Similarly, Japanese students do not expect the teacher to present them with the information needed to finish solving a problem. U.S. teachers, however, tend to step in and tell the students what to do to save the students from frustration (Stigler and Hiebert 1999).

People usually choose a helping profession, such as education, because they are empathetic to the needs of others and want to assist them. As a result, it is difficult to watch another person struggle when faced with a problem that they cannot solve. However, students can be more effectively taught to problem solve when left to struggle and think for themselves. This does not imply that the teacher cannot give a hint or kick-start the thinking process, but if the teacher’s reaction to struggling in the classroom is to tell the students what to do, there is little chance that students will ever think for themselves and learn to apply knowledge to unique problem-solving situations.

**What do I do when a student makes a mistake?**

In a typical classroom situation, a teacher asks a question and calls on a student. If the student has the wrong answer, another student is called on to provide a correction. However, we need to analyze why we ask questions in the first place. Questions should be asked in the classroom to provide a window into student thinking, not to simply obtain a correct answer. With this assumption, any response is welcomed and can be used as a building block to help the entire class make sense of the topic. Remember, too, that even when a student gives a right answer, we cannot always infer that the student understands the mathematics. A classic example is a story told of a fourth grader who quickly simplified 16/64 to 1/4. The teacher was surprised that the student answered the question so quickly, and the student responded, “It was easy. All you have to do is cancel the 6 on the top and bottom.” The common misconception among teachers here is that a wrong answer means that students do not understand the problem or worse yet that a right answer implies that they do.

**CONCLUSION**

Consideration of the results of a study such as the TIMSS can be a worthwhile experience as teachers compare the general findings of the research with what they typically do in their own classrooms. Instead of viewing the results defensively, educators have an excellent opportunity to constructively improve their teaching performances through reflection on practice. In addition to serving as a catalyst for individual reflection, this article could also be used as part of a study group in which all members read the material then gather to discuss their thoughts on the questions raised. Of course, there are no right or wrong answers, and research cannot be expected to provide all the solutions to problems that exist in U.S. schools. However, it is hoped that issues such as teacher beliefs, planning for instruction, and classroom teaching practices can be revisited through reflection on the TIMSS research findings. The best teachers are never satisfied with their work or its results and continue to explore answers to the difficult questions that have been raised.

**REFERENCES**


