Differences across cultures in classroom instruction may contribute to superior performance by Asian children on mathematics achievement tests.

Mathematics Learning in Japanese, Chinese, and American Classrooms

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It might at first glance seem misguided to study cultural differences in learning by focusing on schools. Indeed, the surface features of school mathematics are more similar than different when compared across cultures, and even classrooms in different cultures appear to resemble one another in many respects. Yet schooling is a cultural institution, and more detailed analysis reveals the subtle and pervasive effects of culture as it impinges on children's learning of school mathematics—in the

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curriculum, in the organization and functioning of the classroom, and in the beliefs and attitudes about learning mathematics that prevail among parents and teachers. In this chapter, we will present some of what we have learned about the classrooms in which children learn mathematics in Japan, Taiwan, and the United States.

The decision to compare mathematics learning in Asian and American classrooms is, of course, not arbitrary. We have known for some time now that American secondary school students compare poorly on tests of mathematics achievement with students from many other countries, but especially with students from Japan (Husen, 1967; McKnight and others, 1987; Travers and others, 1985). More recently, Asian-American differences in achievement have been found to exist as early as kindergarten and to be dramatic by the time children reach fifth grade. Stevenson, Lee, and Stigler (1986), for example studied children from representative samples of fifth-grade classrooms in Sendai, Japan; Taipei, Taiwan; and Minneapolis, U.S.A. On a test of mathematics achievement, the highest-scoring American classroom did not perform as well as the lowest-scoring Japanese classroom, and outperformed only one of the twenty classrooms in Taipei. Explaining differences as dramatic as these presents a challenge to researchers and also to educators who must grapple with the problem of declining mathematical competence in American society.

Where should we look for explanations? The fundamental problem we encounter is that almost every dimension on which we could compare Asian countries with the United States proves to differentiate these societies. Given this enormous confounding of factors, it is almost impossible to tell which are causally related to differences in learning and which are only related by chance. Aside from this limitation, however, there is a great deal to learn by understanding the way cultural and educational resources are marshalled to produce the outstanding achievement—at least in the domain of mathematics—produced by Asian societies. In this chapter we focus on classrooms, because classrooms are where most people learn most of what they ever know about mathematics.

Just sitting in a Japanese mathematics lesson can provide us with important insights, not only about the way mathematics is taught in Japan but also about the way mathematics is taught in the United States. We can illustrate this point with an anecdote. Several years ago we visited a mathematics class in a Japanese elementary school where the lesson was on drawing cubes in three-dimensional perspective. The class was typical by Japanese standards: thirty to forty students at their desks arranged in rows, facing the teacher who was standing at the front of the room. Each student was working in his or her notebook, but there also was a great deal of discussion from desk to desk, and the noise level was rather high. The discussions were not inappropriate, however; rather, they were directed almost completely to the mathematical topic at hand.

Against this background, one child was having trouble. His cube looked crooked, no matter how carefully he tried to copy the lines from the teacher's example. And so the teacher asked this child to go to the blackboard and draw his cube. Standing there, in front of the class, he labored to draw a cube correctly while the rest of the students in the class continued working at their desks. After working for five or ten minutes, he asked the teacher to look at his product. The teacher turned to the class and asked, "Is this correct?" The child's classmates shook their heads and said, "No, not really." After some open discussion of where the problem might lie, the child was told to continue working at the blackboard and try again. This scene continued for the duration of the forty-minute class. As the lesson progressed, the group of American observers began to feel more and more uncomfortable and anxious on behalf of the child at the board. We thought that any minute he might burst into tears, and we wondered what he must be feeling. Yet he did not cry and, in fact, did not seem at all disturbed by his plight. At the end of the class he finally drew a passable cube, in response to which the class applauded.

As we later came to learn, scenes like this are not unusual in Japanese classrooms, and later we will show how this one fits into the broader context of mathematics learning in Japan. For now, we want to focus on the effect the experience had on us, because it exemplifies one of the greatest benefits of cross-cultural research for the study of educational processes. When educational researchers look only at classrooms in their own culture, they become accustomed to many of the most predominant characteristics of those classrooms and thus fail to note the significance of those characteristics. American teachers generally do not call children to the board to display their errors, because they fear the possible damage it might do the child's self-esteem. Yet nothing drives us to question this aspect of American teaching more than to be confronted with it in a scenario like the one we have described. The anthropologist Melford Spiro (in press) has described the aim of anthropology as to make the strange familiar and the familiar strange. Nothing could better describe the aim of our research. We hope that our comparisons of Asian and American mathematics education will lead us to question practices that we take for granted and understand practices that we at first find strange.

The information about Japanese, Chinese, and American classrooms we present below comes from two large cross-cultural studies based at the University of Michigan that have investigated academic achievement and its correlates in Japan, Taiwan, and the United States. Data for the two studies were collected in 1979-80 and in 1985-86, and data from the second study are still in the process of being analyzed. Although both of these studies included testing of children and interviewing of parents as part of their designs, we will focus in this chapter on classroom observations. The methods used for observing classrooms differed substantially across the two studies. Yet taken together, they provide us with an integrated view of how mathematics classrooms differ across these three cultures.

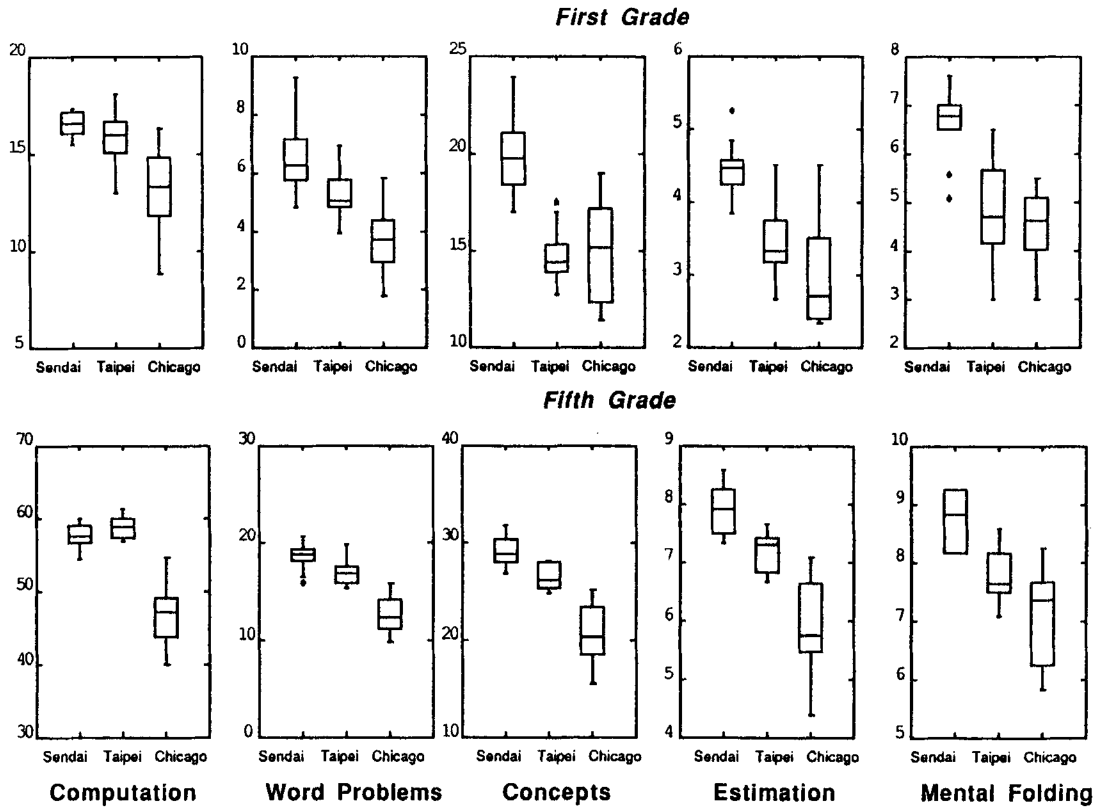
Differences in Mathematical Knowledge

A criticism often voiced in response to our first study was that our test measured mostly computational skills and did not measure abilities that American educators consider to be more important, such as creative problem-solving skills. In our second study we took heed of such criticism by designing tests to sample as wide a variety of mathematical skills and knowledge as possible, thus broadening our understanding of what specific knowledge differences underlie Asian superiority in mathematics achievement. In addition to group tests of computational skills and, for fifth-grade students, basic knowledge of geometry, we constructed ten more tests of mathematics-related knowledge that were administered in two separate individual testing sessions. All of the tests were especially constructed for this study and were judged culturally unbiased by a team of researchers representing each of the cultures being studied. The tests included novel word problems, conceptual knowledge, operations, graphing, estimation, measurement, visualization, mental image transformation, mental calculation, and memory for numbers. A total of 5,524 children across a total of 160 first- and fifth-grade classrooms in the three locations were tested.

Are differences in performance restricted to computational skills, or do Asian students also do better than their American counterparts on tests of other mathematics-related skills? Although we are just beginning our analyses of the test data, the answer is clear: Japanese students, in both first and fifth grades, outscore American students on almost every test we constructed. The pattern of results from Taiwan resembled those from Japan for fifth-graders but were more mixed for first-graders. Let us briefly examine some of these results.

In Figure 1 we present box plots (Tukey, 1977) showing the distribution of school means for five representative tests from the battery. These plots are useful because they indicate both median performance (denoted by the center line) and variability across schools in each of the three locations at both grade levels. The five tests presented in Figure 1 cover a broad range of topics: (1) a test of computational skill; (2) a test of word-problem solving, including both standard and nonstandard types of problems; (3) an intensive interview designed to tap children's conceptual knowledge of mathematics across a wide variety of domains, including place value, equations, and fractions; (4) a test of estimation skills; and (5) a test requiring students to mentally fold an irregularly shaped piece of paper in accordance with verbal instructions.

Figure 1. Box Plots Showing Distribution of School Means of Number Correct on Five Representative Mathematics-Related Tests



At the left-hand side of Figure 1 are the results of the test of computational skills. These results replicate those found in our earlier study (Stigler, Lee, Lucker, and Stevenson, 1982), even though the American children were sampled from Chicago instead of Minneapolis. At first grade, the Japanese and Chinese schools both score higher and are less variable than are the American schools, and this pattern is even more pronounced in the fifth grade. Moving to the right, we see a similar pattern for performance on the test of word problems. It is important to note that by the time students reach the fifth grade, there is almost no overlap in the distributions of Asian and American students.

The next three tests presented in Figure 1—conceptual knowledge, estimation, and mental folding—differ from the first two in that they are made up of questions not typically encountered as part of the mathematics curricula in any of the three locations. Interestingly, they also show a different pattern of results than we saw in the tests of computation and word problems. In first grade, students in Sendai are scoring far higher than are students in either Taipei or Chicago, who are performing approximately equally well. By the time they reach fifth grade, however, the students from Taiwan have passed their American counterparts and are approaching the level of performance attained by the Japanese.

In summary, the Asian advantage in mathematics, at least at the elementary school level, is not restricted to narrow domains of computation but rather pervades all aspects of mathematical reasoning. These findings should provide ample motivation for examining cultural differences in the way mathematics is learned in Japanese, Chinese, and American classrooms.

Methods for Classroom Observations

First Study. The first study was conducted with a sample of first- and fifth-grade elementary school students and teachers in Sendai, Japan; Taipei, Taiwan; and the Minneapolis metropolitan area. In each city, ten representative schools were selected, and within each school two first- and two fifth-grade classrooms participated, yielding a total of 120 classrooms across the three cities. Each classroom was visited forty times over a two- to four-week period. The visits were scheduled to yield a stratified random sample of time across the school day and school week, thus making it possible to estimate the amount or percentage of time that was devoted to various activities. (A full description of the method can be found in Stigler, Lee, and Stevenson, 1987.)

Each visit lasted about an hour and included time for separate observations of teachers and of individual students. We used a time-sampling procedure to observe the target—either teacher or child—for ten seconds, and then to spend the next ten seconds coding the presence or absence of a checklist of categories. This procedure was repeated according to a predefined sequence that counterbalanced order of observation across the teacher and the twelve randomly chosen target students in each class. Across the two- to four-week observation period, each of the twelve children in each classroom was observed for about thirty-three minutes (not including coding time), and each teacher was observed for about 120 minutes.

The student coding system included thirty categories, although coding was eased somewhat by the fact that many of the categories were mutually exclusive. Various aspects of the classroom were coded from the target child's point of view, including the following: whether the class engaged in academic activities or in transition between activities, what subject matter was being taught, how the classroom was organized and who the leader was of the child's activity, and what kinds of on- and off-task behaviors the child was engaged in.

The teacher coding system contained nineteen categories. These categories described who the teacher was working with, what kinds of teaching behaviors the teacher was engaged in, and what kinds of feedback the teacher was offering to the students. Specific categories from the student and teacher coding schemes will be introduced as the results are presented.

Second Study. The second study was again conducted in Sendai, Japan, and Taipei, Taiwan. In the United States, however, we decided to move our study to the Chicago metropolitan area, which is far more diverse in population than Minneapolis and thus more representative of mainstream America. In each of the two Asian cities, ten schools were selected to participate in the study. In the Chicago area, twenty schools were chosen to represent the urban and suburban areas that make up Cook County. Twenty rather than ten schools were chosen, because Cook County is more diverse than either of the Asian cities. Within our Chicago sample, we included public and private schools; upper, middle, and lower socioeconomic status neighborhoods; predominantly black, white, Hispanic, and mixed ethnic schools; and urban and suburban environments. As in the first study, two first-grade and two fifth-grade classrooms from each school were selected to participate in the study, yielding a total sample of 160 classrooms in the three locations.

Observations for the second study differed in two important ways from observations conducted in the first study. First, only mathematics classes were observed. Second, detailed narrative descriptions of each class were recorded, yielding a far richer source of information than we had available from the first study.

Each of the 160 classrooms in the mathematics study was visited four separate times over a one- to two-week period, yielding a total of 640 observations across the three locations. Observers, who were local residents of each city, arrived just before teachers began the daily mathematics lesson and observed until the mathematics class was over.

The observers were instructed to write down as much as they could about what was transpiring during the class. Their goal was to record the ongoing flow of behaviors and to include descriptions of all supporting materials (for example, what was written on the blackboard, how many children were working on which problem, and so on). The observers also noted, with marks in the margin, when each minute of time had elapsed. These minute markers were included so that we would be able to estimate the duration of various activities.

The observations produced 640 different narrative descriptions of mathematics classes, in three different languages. Not all observations were of equal quality: the observations varied in both detail and consistency. How were we to code and summarize the data into a form that would be useful in characterizing cross-cultural differences in mathematics teaching?

We first convened a group of bi- and tri-lingual coders to read all of the observations and to summarize their contents in English. In addition, a subset of the observations was translated verbatim into English. From these, we developed a feel for the range of situations we would have to code and some intuitions about cross-cultural differences. We then constructed a coding system that contained some predefined categories but that also included procedures that would preserve detail.

Each observation was divided into segments as the basic unit of analysis. A segment was defined as changing if there was a change in either topic, materials, or activity. Topics were globally defined, including categories such as telling time, measurement, or addition facts. Materials included such items as textbooks, worksheets, the blackboard, or flashcards. Activities, again, were rather molar: examples included seatwork, students solving problems on the blackboard, or teachers giving explanations. The categories were not intended as the full description of the class but rather as a way of organizing the information into a more useful format. As it turned out, there were not large cross-cultural differences in either the average number of segments that comprised a lesson (five to six segments in first grade, six to eight in fifth grade), or the average duration of each segment (seven to eight minutes in first grade, five to six in fifth grade).

In addition, an English language summary was constructed of each segment that would recapitulate in some detail what was going on during the segment. The summaries were standardized somewhat by the use of keywords that would alert us to the presence or absence of certain categories in the classroom. For example, whenever a student was observed asking a question of the teacher, the summary would include the standard keyword "S-to-T," which would facilitate a computer search for all such situations. Our goal was to make the summaries as consistent as possible in style and language.

Time, Organization, and Disorganization: Findings from the Objective Coding

The results of the first observational study served mainly to differentiate classrooms in the United States, on one hand, from classrooms in Japan and Taiwan, on the other. Very few differences emerged between Chinese and Japanese classrooms. In some respects, one only has to visit one Chinese or Japanese classroom to see vast differences between Asian and American elementary school classrooms. Class size is a major difference: while the classrooms in our Minneapolis sample average twenty-two students in the first grade and twenty-four students in the fifth grade, the classrooms in Taipei average forty-five and forty-eight students at the two grade levels, and those in Sendai, thirty-nine at both grade levels. Most Asian classrooms are arranged with desks in rows facing the teacher, while American classrooms often have desks arranged in groups.

The two dimensions on which the Asian observations differed most from the American ones were time spent in the teaching and learning of mathematics and the level of organization in the classroom.

Time. Children in Japan and Taiwan spend significantly more time in school than do American children, and this ultimately translates into significantly more time learning mathematics. School is in session 240 days per year in both Japan and Taiwan, compared to only 180 days per year in the United States. Although first-graders in all three cities that we studied spent about thirty hours per week in school, fifth-graders in Sendai spent thirty-seven hours a week in school, those in Taipei, forty-four hours, and those in Minneapolis still only thirty hours.

During academic classes, Chinese and Japanese children at both grade levels spent a much higher percentage of their time engaged in academic activities than did American children. In first grade, American, Chinese, and Japanese children spent 69.8 percent, 85.1 percent, and 79.2 percent of the time, respectively, engaged in academic activities. At the fifth grade the corresponding percentages were 64.5 percent, 91.5 percent, and 87.4 percent. Furthermore, although the percentage increased between first and fifth grade for the Asian children, the percentage actually declined slightly across grade levels for the American children.

The majority of class time in all three cultures was devoted to either reading/language arts or mathematics, and although the total percentage of time devoted to either one of these subject matters was similar across the three cultures, the way time was apportioned between the two varied significantly by culture. American teachers at both grade levels devoted more time to reading/language arts and less time to mathematics than

Table 1. Number of Hours Each Week Spent in Language Arts and Mathematics

	Country		
	U.S.A.	*Taiwan*	*Japan*
First Grade			
Language arts	10.6	10.5	8.8
Mathematics	2.9	3.9	6.0
Fifth Grade			
Language arts	8.2	11.2	7.8
Mathematics	3.4	11.4	7.6

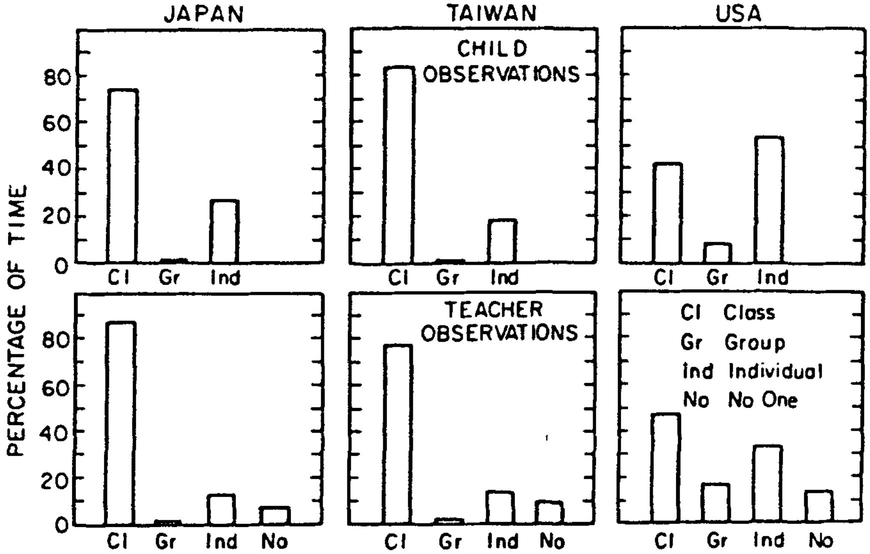
did Chinese and Japanese teachers. By the fifth grade, both Chinese and Japanese teachers spent approximately equal time teaching mathematics and reading. American teachers, by contrast, spent almost three times as much time on reading as they did on mathematics.

Calculations based on the hours per week spent in school, the percentage of time spent in academic activities, and the percentage of time those academic activities were mathematics versus reading/language arts allow us to estimate the number of hours each week children in the three cultures spend working on the different subject matters. The results of these calculations are presented in Table 1. The cross-cultural differences in the number of hours devoted to mathematics instruction are large, sufficiently large, in fact, that they could go a long way toward explaining the cross-cultural differences in mathematics achievement.

Organization. The second dimension that differentiated American mathematics classrooms from those in Japan and Taiwan was the way in which the classrooms were organized. Classrooms in Japan and Taiwan were centrally organized, with most activity under the direct control and supervision of the teacher, while classrooms in the United States were more decentralized in their structure and functioning. Correlated with this difference in type of organization was a difference in the amount of disorderly, off-task behavior present in the classrooms, such that the American classrooms, where there was less direct control by the teacher, also evidenced more off-task behavior.

These differences in type of classroom organization were indexed by several categories in our observational coding scheme. The upper panel of Figure 2 shows the level of organization of the classroom as coded in the observations of children. Japanese and Chinese students spent the vast majority of their time working, watching, and listening together as a class and were rarely divided into smaller groups. American children, by contrast, spent the majority of their time working on their own and a smaller amount of time working in activities as a member of the whole

Figure 2. Percentage of Time Spent in Various Classroom Organizations



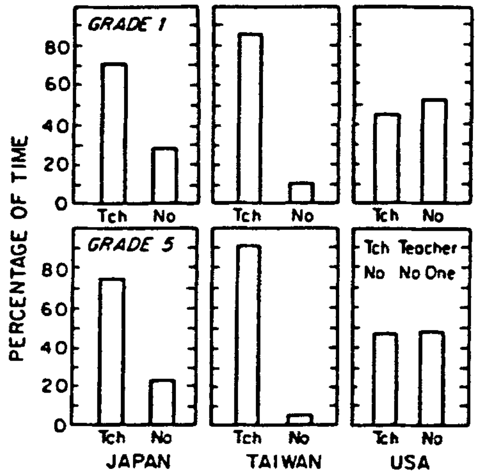
Source: Stigler, Lee, and Stevenson, 1987.

class. The same picture emerges when teachers are observed (the lower panel of Figure 2). American teachers spent more time working with individuals and less time working with the whole class than did Chinese or Japanese teachers. In addition, American teachers were coded as working with no students 13 percent of the total time in mathematics classes, as opposed to only 6 percent of the time for Japanese teachers and 9 percent of the time for Chinese teachers.

The counterpart of these findings is displayed in Figure 3, where we see what percentage of the total time in mathematics classes students were part of a teacher-led activity and what percentage they were part of an activity with no leader. In Taiwan the teacher was the leader of the children's activities 90 percent of the time, as opposed to 74 percent in Japan and only 46 percent in the United States. No one was leading the students' activity 9 percent of the time in Taiwan, 26 percent of time in Japan, and 51 percent of the time in the United States.

Taken together, these findings indicate that classrooms in the Asian cultures are organized more hierarchically than are classrooms in the United States, with the teacher directing energies to the whole class and with students more often working under the direct supervision of the teacher. Because of these differences in organization, American students experience being taught by the teacher a much smaller percentage of time than do the Asian students, even though American classes contain roughly half the number of students.

Figure 3. Percentage of Time Students Spent in Activity Led by Teacher and by No One



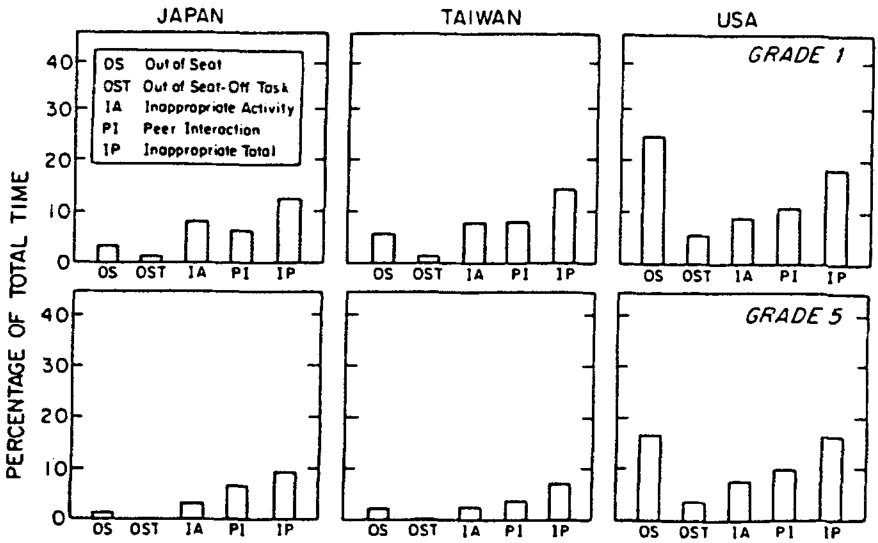
Source: Stigler, Lee, and Stevenson, 1987.

Associated with the relatively decentralized organization that characterizes American classrooms is a higher level of disorderly behavior. This disorderliness was revealed in our coding of the incidence of inappropriate or off-task student behaviors. If the target child was not doing what the teacher expected him or her to do, he or she was judged as being off-task. Two categories of off-task were distinguished: those behaviors involving inappropriate peer interaction and those the target child engaged in alone. In addition we coded whether or not the target child was out of his or her seat. The results from these observations are presented in Figure 4.

There were large cross-cultural differences in the overall percentage of time students spent engaged in inappropriate, off-task activities. Across both grade levels, American students were off-task 17 percent of the time during mathematics class, as opposed to only 10 percent of the time for Chinese and Japanese students. Unfortunately, we did not code what students were actually doing but only that they were not behaving in accordance with classroom norms as defined by the teacher. Thus, we do not know whether some of the behavior coded as off-task might nevertheless have been oriented toward academic goals.

American students were coded as being out of their seats during mathematics classes 21 percent of the time, whereas Chinese and Japanese children were out of their seats 4 percent and 2 percent of the time, respectively. Of course, being out of one's seat does not necessarily imply that one is off-task, particularly in American classrooms. However, if we look at the percentage of time students were both out of their seats and

Figure 4. Percentage of Time Spent in Inappropriate Activities



Source: Stigler, Lee, and Stevenson, 1987.

off-task, the American percentage was five times as high as that in the other two countries (5 percent versus less than 1 percent in Japan and Taiwan).

Problem Solving, Evaluation, and Coherence: Preliminary Ideas from the Narrative Observations

The data derived from the first observational study is informative, up to a point: we get basic information about how time is spent by students in the three countries and about how frequently classrooms are organized in various ways. The limitation of these data is that we learn very little about how mathematics is actually taught in the three cultures. In contrast, the narrative observations collected in the current study provide us with richly detailed information concerning what happens in mathematics classes in Sendai, Taipei, and Chicago. In the remainder of this chapter we will present some ideas based on preliminary analyses of the narrative records.

Three ways in which classrooms in the three cultures were observed to vary were in the nature of mathematical problem-solving activities, the methods by which student work was evaluated, and the coherence of lessons from the child's point of view.

Problem Solving. A major component of mathematics lessons in all three cultures involves learning how to solve, and then solving, mathematical problems. However, the styles of learning and instruction that surround problem solving, as well as the formats in which problems are presented, appear to differ greatly across cultures.

Reflection Versus Performance. In terms of style, classrooms vary in the degree to which they emphasize performance and practice, on the one hand, versus reflective thinking and verbalization, on the other. Chinese classrooms differ from Japanese classrooms in this regard: the Chinese classrooms are more performance oriented and the Japanese classrooms more reflective. American classrooms are not at all reflective, as are Japanese classrooms, nor do they place a consistent emphasis on performance, as do Chinese classrooms.

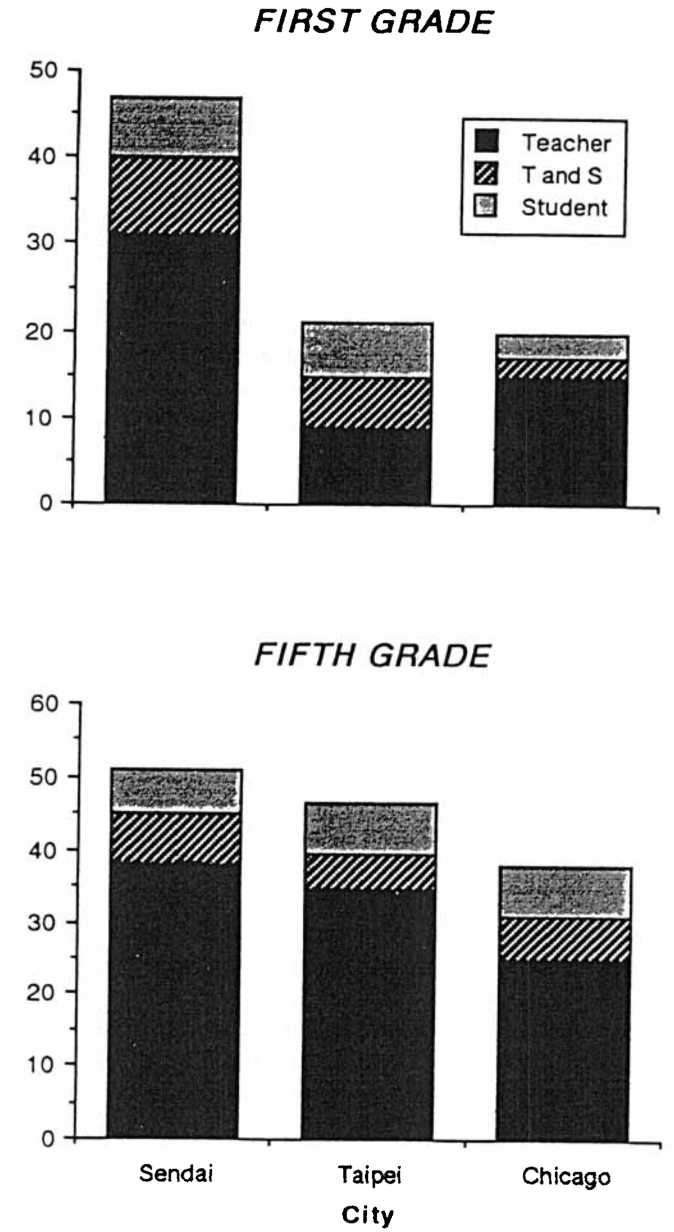
One index of reflectivity is simply the amount of verbal explanation, both by teachers and by students, that occurs during mathematics lessons. The percentages of segments that contained verbal explanations by the teacher, a student, or both are presented in Figure 5. In the first grade, 47 percent of all Japanese segments contained verbal explanations, compared to 21 percent of Chinese segments and 20 percent of American segments. By fifth grade, the incidence of explanations in classrooms in Taipei and Chicago has increased to 47 percent and 38 percent, respectively, but the incidence of explanations has increased in the Japanese segments as well, up to 51 percent. Clearly, there is more verbal discussion of mathematical concepts and procedures in Japanese classrooms than there is in either Chinese or American classrooms, and this difference is most pronounced in the first grade.

Indeed, when visiting a Japanese mathematics class, one detects a more relaxed pace than occurs in either Chinese or American classrooms. Japanese teachers tell students it is the process of problem sovling that matters, not simply getting the correct answer. Japanese teachers thus often try to slow their students down, asking them to think about a problem and how to solve it, then discuss their thoughts with the class, rather than rushing on to solve the problem. Interestingly, Japanese fifth-grade teachers asked their students not to solve but to think about a problem in 7 percent of all segments, something that occurred in only 2 percent of the Chinese and American segments.

Chinese teachers, on the other hand, emphasize fast and accurate performance, or getting the right answer quickly. For example, 17 percent of all Chinese segments were devoted to practicing rapid mental calculation, an activity that was never observed in either the Japanese or American classrooms. It appears that Chinese teachers emphasize "do," the Japanese teachers emphasize "think."

Manipulatives and Real-World Scenarios. One might expect that the Japanese emphasis on reflection and verbalization would imply less reliance on concrete manipulatives or real-world problems. In fact, however, this was not the case. Both Japanese and Chinese teachers, as we

Figure 5. Percentage of Segments with Explanations from Teachers Only, from Students Only, and from Both Teachers and Students



will show, relied more on manipulatives and real-world problem situations than did teachers in our Chicago sample.

The use of concrete and real-world materials during classroom instruction was coded in two categories: (1) concrete manipulatives (for example, presented with eighty discrete objects, children are asked to divide them into four equal groups) and (2) real-world scenarios, which included word problems, dramatic enactments of mathematically solvable real-world problems, or the (relatively infrequent) situation where students are asked to generate a word problem to correspond with a symbolic equation. We assume that segments in which neither manipulatives nor real-world problems were used depended primarily on symbolic mathematical materials for instruction.

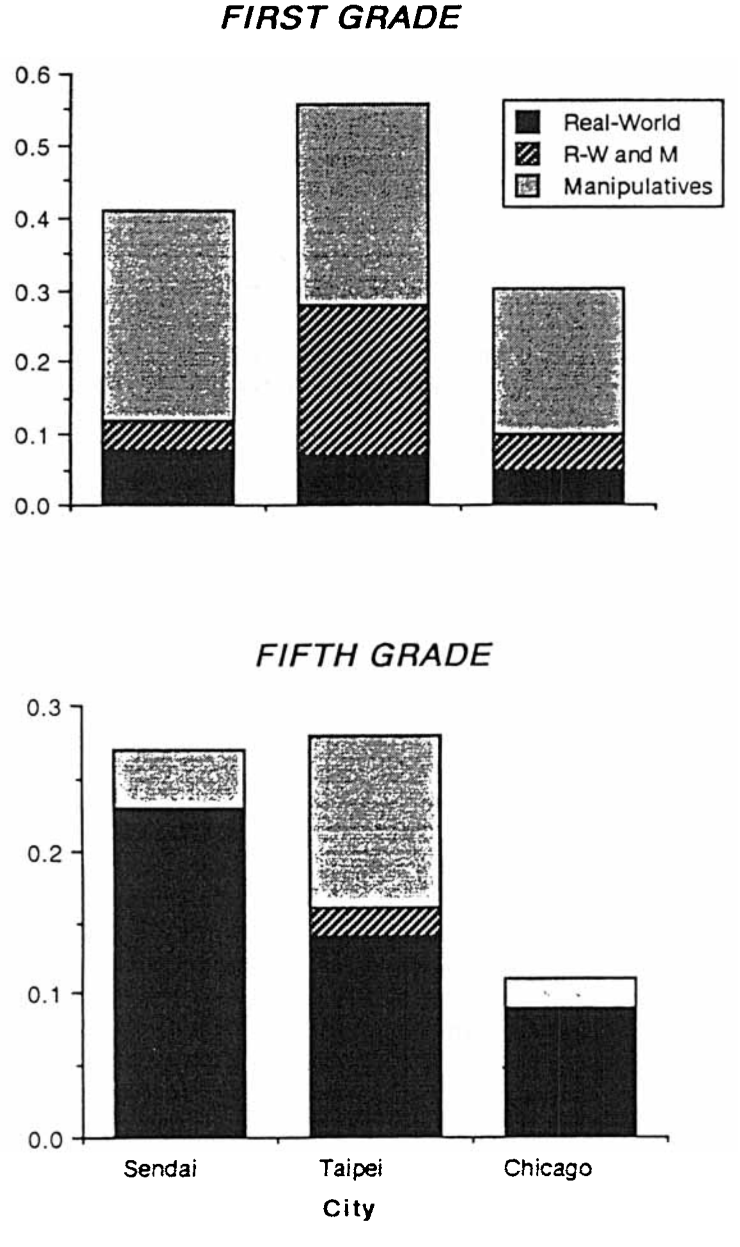
The percentages of instructional segments in which problems were presented using concrete manipulatives, real-world scenarios, or both are presented in Figure 6. The upper panel of Figure 6 shows that in first grade, both manipulatives and real-world scenarios are used more frequently in Taipei than in either Sendai or Chicago and more frequently in Sendai than in Chicago. In the fifth grade (lower panel of Figure 6), teachers in all three cultures have increased their use of real-world scenarios while at the same time reducing their reliance on manipulatives. However, there still are large differences between the three cultures on both counts: Sendai shows the largest proportion of segments in which real-world scenarios are used, and Chicago shows the least. Taipei teachers, on the other hand, use more manipulatives in fifth grade than do teachers in the other two locations, whereas Chicago teachers use the least. Thus, although Japanese and Chinese teachers differ in the degree to which they use manipulatives versus real-world content in their teaching of problem solving, both groups of Asian teachers use far more manipulatives and real-world problems combined than do the American teachers.

Children learn not only from the way that problems are presented but also from the type of feedback they receive and the manner in which that feedback is provided. Children are also sensitive to the ways that lessons are structured. Thus, two additional factors that seem to distinguish mathematics classrooms in Japan, Taiwan, and the United States are (1) the way in which feedback is provided to students, and (2) the degree to which students are provided with opportunities to construct coherent representations of mathematics lessons.

Evaluation. Students' work is evaluated frequently in classrooms. We have found that both the frequency of and the approach to evaluations of students' mathematical solutions differ in the three cities.

Our first analysis reveals the frequency with which children's work is evaluated in the three cities. In first-grade mathematics lessons, 7 percent of all segments in Chicago were devoted to evaluation, whereas 12 percent

Figure 6. Proportion of Instructional Segments Using Concrete Manipulations, Real-World Scenarios, or Both



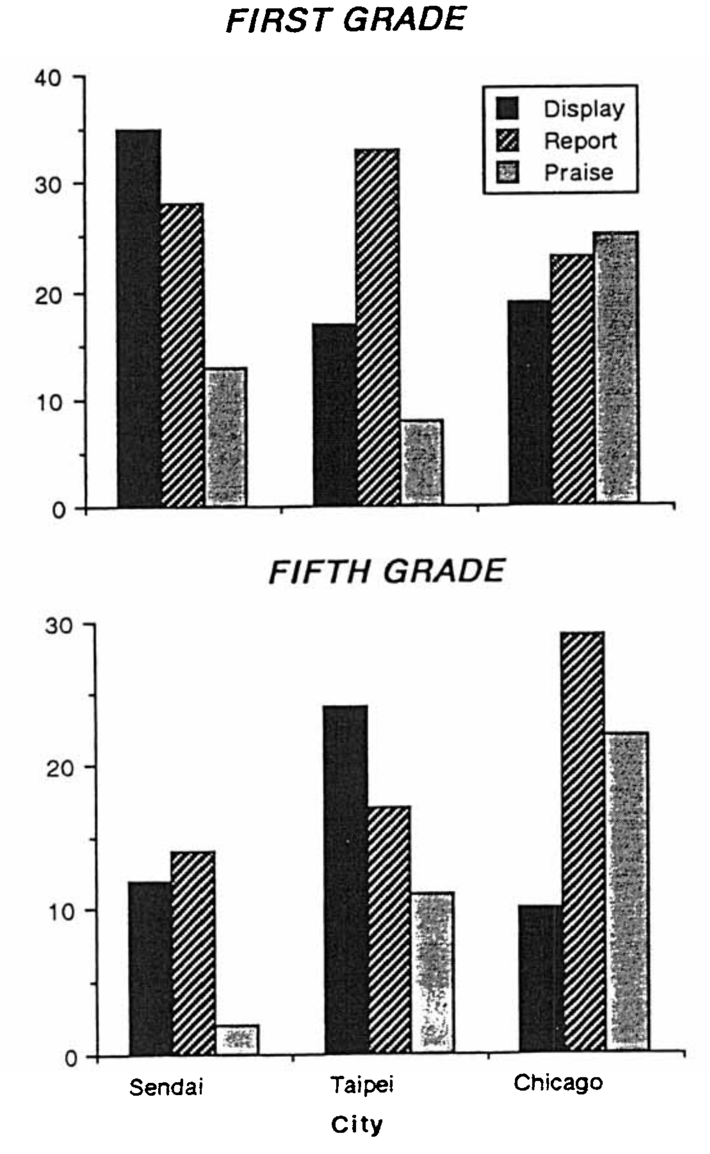
of segments in Sendai and 13 percent in Taipei were devoted to evaluation. Although evaluation segments occurred more often in fifth grade than in first grade, there were fewer such segments in the fifth grade in Chicago (14 percent) than in Sendai (17 percent) or Taipei (18 percent). Furthermore, although the evaluation that occurs in lesson segments devoted to evaluation is usually public and visible to the whole class, this was less true in Chicago than it was in Sendai or Taipei. Thus, students in Chicago have somewhat less opportunity to have their own work evaluated, and to observe the evaluation of other students' performance, than do students in the two Asian cities.

In addition to the differences in frequency of evaluation, we also have discovered differences in the methods used for evaluating students' work. Each evaluation segment was coded for how the students' answers were treated. In analyses of segments in which evaluation was the primary activity, the three most common methods of evaluation were as follows: (1) displaying a student's erroneous solution and reworking the problem until a correct solution was derived, (2) having students report to the class how many problems in a set of problems were solved correctly (for example, the teacher asks all students who solved all problems correctly to stand up), and (3) praising or rewarding students for their efforts and/or correct solutions. Not all evaluation segments used one of these three methods, but a sizable percentage did. Figure 7 presents the percentage of public evaluation segments in each country and grade level that employed each of the three methods. (It was only possible to code public evaluation segments, since only public evaluation was visible.)

It is clear from Figure 7 that the predominant methods for evaluating students differ for the students in the three cities and also differ from the first to the fifth grade. First-grade Japanese students are frequently evaluated by having their errors displayed to the class. These errors are then discussed, and correct solutions are derived by class members. This type of evaluation occurs in 35 percent of all first-grade evaluation segments in Sendai but in only 17 percent of the Taipei and 19 percent of the Chicago first-grade evaluation segments. The most prevalent type of evaluation in Taipei was reporting to the class the number of problems correctly solved. This occurs in 28 percent of the Sendai, 33 percent of the Taipei, and 23 percent of the Chicago first-grade evaluations. The most prevalent type of evaluation found in the Chicago first-grade segments was praising students. Thus, in the first grade, the Japanese students are revising their incorrect attempts, the Chinese students are letting the class know how well they performed, and the American students are being told that they have done a good job.

The picture changes somewhat when we examine the evaluations that occur in the fifth grade. Fifth-grade students in Taipei are often evaluated by having their errors displayed to their classmates (in 24 per-

Figure 7. Percentage of Evaluation Segments Containing Different Kinds of Feedback



cent of the evaluation segments), whereas this happens less frequently in Sendai (in only 12 percent of the evaluation segments) and in Chicago (in only 10 percent of the evaluation segments). The fifth-grade students in Chicago and in Sendai are evaluated most frequently by announcing how many problems they solved correctly. However, this happens much more in Chicago (in 29 percent of the evaluation segments) than in either Sendai (in 14 percent of the evaluation segments) or in Taipei (in 17 percent of the evaluation segments). And finally, students in Chicago are still receiving more praise (22 percent of the evaluation segments) than are students in either Sendai (2 percent) or Taipei (11 percent).

Coherence. This last dimension is also the most speculative and difficult to document. Having read the corpus of narrative observations, we are left with the impression that Japanese classrooms in particular, and Chinese classrooms to some extent, are structured in a more coherent fashion than are American classrooms. We use the word *coherent* very much in the way researchers studying text comprehension use the word. A text is coherent to the extent that it enables or allows the comprehender to infer relations between events (Trabasso and van den Broek, 1985). In like manner, teachers who provide a basis for children to infer reasons for and relations between events provide the basis for coherence in the classroom. Work by Trabasso, Stein, and others has shown that coherence across events in a story has a profound impact on the ease with which the reader can encode, understand, and remember the events of a story (Trabasso and van den Broek, 1985; Stein and Policastro, 1984). Our speculation is that mathematics lessons, too, may be easier to comprehend, and students likely to learn more, when the episodes that comprise the class are coherent.

The analogy between a story and a mathematics classroom is not perfect, but it is close enough to be useful for thinking about the process by which children might construct meaning from their experiences in mathematics class. A mathematics class, like a story, consists of sequences of events related to each other and, hopefully, to the goals of the lesson. What we tend to find in the American observations, unfortunately, are sequences of events that go together, much like those in an ill-formed story. If it is difficult for adult observers to construct a coherent representation of the events that constitute a first- or fifth-grade mathematics class, then it surely would be even more difficult for the average child sitting in those classes to do so.

What, specifically, do we see in Asian classrooms that lead us to perceive them as being more coherent? One possibility is the small amount of time, relative to American classrooms, that is spent on transitions from one activity to another and on irrelevant interruptions. In American first-grade classrooms, a total of 21 percent of all segments contain transitions or irrelevant interruptions, compared to 7 percent in Sendai and

14 percent in Taipei. In fifth grade the corresponding percentages are 15 percent, 3 percent, and 3 percent. Rarely is the logical flow of an Asian class broken to pursue less mathematically important business (such as the time-consuming distribution of materials) that may give students the wrong idea about what is important about mathematics.

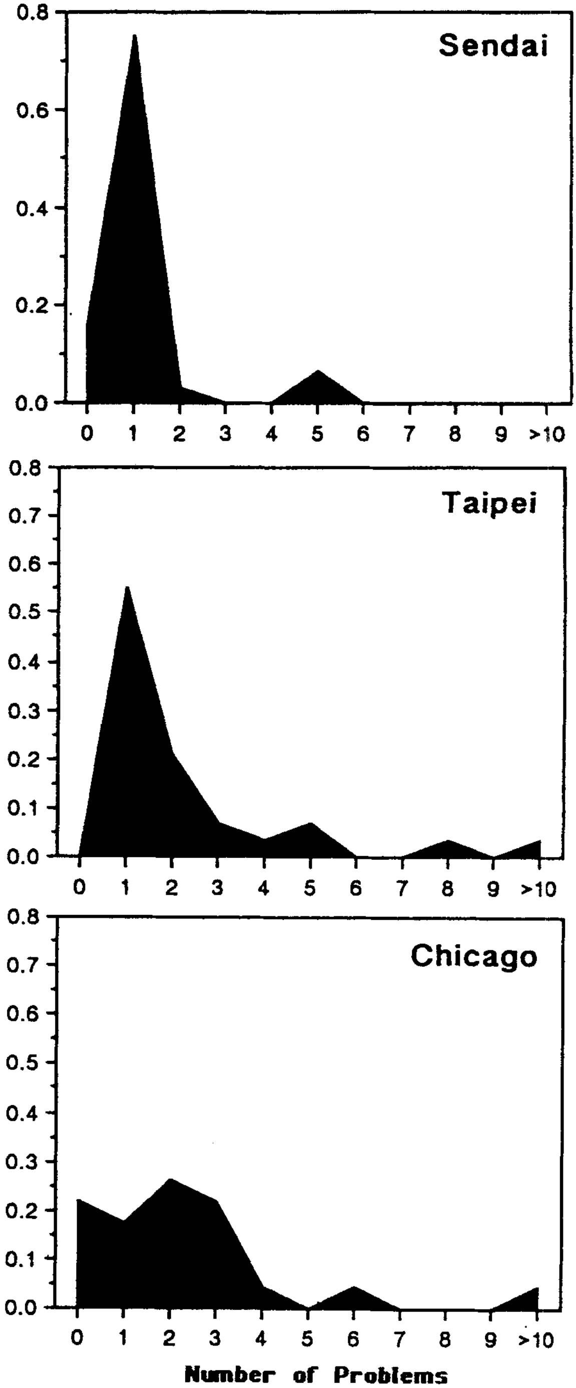
Another aspect of Asian classrooms that may facilitate coherence is a tendency we observed both in Japan and Taiwan to devote an entire forty-minute mathematics class to the solution of only one or two problems. In such a lesson, students might discuss the features of the problem, solve the problem using alternative methods, discuss and evaluate the alternative solution strategies, model the problem using manipulatives, and so on. The problem thus serves to provide topical continuity across the different segments of a lesson, much as a protaganist's goals and purposes provide continuity across the events of a story.

Assuming that a lesson with fewer problems is more coherent than one with more problems, it is worthwhile to ask whether there is, in fact, a large difference in number of problems presented across Japanese, Chinese, and American mathematics lessons. In a preliminary analysis, we counted the number of problems presented during fifth-grade instructional segments that lasted five minutes (the median length of all fifth-grade segments with ongoing instruction). The distribution of five-minute segments over number of problems presented is shown in Figure 8. What we find is that 75 percent of all five-minute instructional segments in Sendai focused on only one problem, compared to 55 percent of the segments in Taipei and only 17 percent of the segments in Chicago.

The devotion of even five minutes to a single problem was relatively rare in American classrooms, not to mention spending an entire class period on only one problem. In no class did we observe an American teacher sticking with a single problem for an entire class. Indeed it appears that American teachers value just the opposite approach. In recent research that examined characteristics of expert mathematics teachers in the United States, it was reported that the expert elementary mathematics teacher can get through forty problems in a single class, whereas the novice teacher may only cover six or seven problems (Leinhardt, 1986; Leinhardt and Greeno, 1986). It would appear that the Japanese or Chinese teacher is striving for a different goal. Or perhaps they are just adapting to a different reality: The value placed on homework in both of these Asian cultures means that repetitive practice can be accomplished at home and class can be reserved for teaching. American teachers must, especially at the first-grade level, accomplish both purposes during the school day.

It is important to note that sticking to one problem does not imply a boring class that lacks variety. Variety, as indexed by change in segment, is approximately equal across the three cultures. For example, the typi-

Figure 8. Distribution of Five-Minute Instructional Segments by Number of Problems Covered



cally first-grade mathematics class in all three cities consists of five or six segments, each lasting seven or eight minutes. What is different is the nature of the changes that occur from one segment to another. While in Japan and Taiwan segment changes are more often coded because of changes in materials or activities without a change in topic being taught, in American classrooms changes are more often coded because of a change in the topic being taught (also see Berliner and Tikunoff, 1976). In the first grade, changes in segments in Japan were due to a change in topic only 7 percent of the time, in Taiwan, 16 percent of the time, and in the United States, 25 percent of the time. This pattern is even more striking in the fifth grade: changes in segments in Japan were due to a change in topic only 1 percent of the time, in Taiwan, only 3 percent of the time, and in the United States, 17 percent of the time. Thus, the students in our Chicago sample must have had to change gears more frequently than their peers in Taipei and Sendai, within the bounds of a single mathematics lesson. And it is important to remember that changing topics does not mean merely a change in problem but rather a change on the order of starting with measurement and moving to multidigit addition. For example, one first-grade American class started with a segment on measurement, then proceeded to a segment on simple addition, then to a segment on telling time, and then to another segment on addition. The whole sequence was called "math class" by the teacher, but it is unclear how this sequence would have been interpreted by a child. In this case, it seems that it would be impossible for anyone to construct a coherent account of the whole class.

In other cases, where the topic does not change within a lesson, the sequence itself could be construed coherently, but American teachers do little to help the child construct a coherent representation. A good example of this kind of situation is provided by the topic of measurement as it is normally taught in first-grade classrooms. Most American textbooks teach fundamental measurement in the following sequence: First they teach children to compare quantities directly and to say which is longer, wider, and so on. Next, nonstandard units of measurement are introduced, and children are taught to ascertain, for example, how many paper clips long their pencils are. Finally, students are introduced to the concept of standard units and taught to measure objects in inches or centimeters. This is a sensible sequence and could conceivably be taught in a coherent manner.

Let us examine the way in which this sequence is implemented in one American classroom in our sample. In the first segment, the teacher has children examine objects—pencils, crayons, paperclips, chalk, and so on—and compare them to determine which are longer. The teacher then moves the class to the next segment and says:

> OK, open your workbooks to page 12. I want you to measure your desk in pencils, find out how many pencils it takes to go across your desk, and write the answer on the line in your workbooks. [Children carry out instructions.] Ok, the next line says to use green crayons, but we don't have green crayons so we are going to use blue crayons. Raise your hand if you don't have a blue crayon. [Teacher takes approximately 10 minutes to pass out blue crayons to students who raise their hands; coded as a transition segment.] Now write the number of blue crayons next to the line that says green crayons. [Teacher then moves on to the third segment.] OK, now take out your centimeter ruler and measure the number of centimeters across your desk and write the number on the line in your workbooks.

What is fascinating about this particular class is that there is absolutely no marking by the teacher of the transition points—the three segments just follow each other as though there were no transition. There is no discussion of how each exercise is important in providing students with an understanding of measurement, no discussion of why units are important or why standard units are important, no discussion of historical development of measurement procedures that could provide more meaning to the sequence of activities, and no discussion of the goals of the class and how each activity relates to those goals. More time is devoted to making sure students have a blue crayon—which is totally irrelevant to the purpose of the lesson—than to conveying the purpose of the three segments on measurement. If we put ourselves in the child's position, what is the likelihood that we would construct a coherent, meaningful account of this particular class?

In Chinese classrooms, and in Japanese classrooms to an even greater extent, we see teachers explicitly pointing out to children the relationships that obtain between different segments within a lesson and between different lessons. For example, one Japanese first-grade teacher was quoted as asking this question of a student at the beginning of a mathematics class. "Would you explain the difference between what we learned in the previous lesson and what you came across in preparing for today's lesson?" To hear a question of this sort posed to a six-year-old would be surprising to most American educators. Perhaps more surprising is that the student was able to answer the question.

As another example, a teacher might draw parallels between a problem solved symbolically and the same problem solved with concrete manipulatives. In both of these examples, the students are given the opportunity to infer coherence across the episodes that constitute their experience in mathematics class. Transitions in the Asian classes often are marked by verbal discussion of the relation between two segments, and classes, especially in Japan, often start with the teacher explaining the goal of the day's class and how the activities relate to the goal. In our narrative data, we found that the Japanese teachers were twice as likely to make explicit reference to connections across episodes than were either the Chinese or American teachers (9 percent of all segments, compared to 5 percent and 4 percent).

In sum, the children we observed in our American sample are faced with a very difficult task: they are required to solve many problems on their own, and often there is no apparent link among the types of problems they are being asked to solve. This clearly differs from the way mathematics classes proceed in Taipei and Sendai. Although the Chinese and Japanese lessons were different on many dimensions, children in both of these cultures were given better opportunities to construct mathematical concepts and also were given more opportunities to get public feedback about whether their constructions were accurate.

Conclusion

Japanese and Chinese elementary school students are learning more about all aspects of mathematics than are their peers in the United States. Although there are many possible explanations for these differences, we have chosen, in this chapter, to focus on classrooms, since classrooms are the context in which most children learn mathematics. What we have found is not surprising, given the cross-cultural differences in achievement: classrooms in Sendai and Taipei differ markedly from those in our American samples on a number of dimensions.

In our first study, which employed a time-sampling objective coding scheme, we found that students in both Sendai and Taipei spend a great deal more time in mathematics class than do American students and that they spend less time during mathematics class engaged in off-task, inappropriate behaviors. We also found that classrooms are organized differently in the Asian cultures. Whereas Asian students spend most of their time working on teacher-led activities as members of a whole class of students, American students spend more time working independently, with contact with the teacher more likely to take the form of individualized or small-group instruction. These differences in organization mean that American students spend much less time in school being attended to by the teacher, if we assume that students working as members of a whole class feel that the teacher is working with them.

Why do we organize our U.S. mathematics classes in the way that we do? Some part of the answer can be tied to cultural beliefs about the nature of individual differences and the nature of learning. In other research conducted by the Michigan group, we have found that American mothers are more likely to see mathematical ability as innately determined than are Asian mothers (Stevenson, Lee, and Stigler, 1986).

Because we tend to think individual children are inherently unique in their limitations, we believe that the education appropriate for one child may not be appropriate for another, and thus we tend to emphasize individualized learning. Asian educators are more comfortable in the belief that all children, with proper effort, can take advantage of a uniform educational experience, and so they are able to focus on providing the same, high-quality experience to all students. Our results suggest that American educators need to question their long-held assumption that an individualized learning experience is inherently a higher-quality, more effective experience than is a whole-class learning experience. Although it may be true that an equal amount of time with a teacher may be more effective in a one-on-one situation than in a large-group situation, we must realize that the result of individualized instruction given realistic financial constraints is to drastically reduce the amount of time a teacher can spend with any individual student.

In our narrative observations, preliminary analyses again revealed a number of differences in the way mathematics is taught in Asian and American classrooms. Asian students are given more opportunities for solving real-world problems, and Japanese students, in particular, spend a far greater amount of time than do either Chinese or American students engaging in reflective verbalization about mathematics. We also found a greater reliance on public evaluation of both the products and the processes of students' problem-solving efforts. In Japan the most common form of evaluation involved children putting their incorrect solutions on the blackboard for all to see and then having the whole class discuss the nature of the error and possible ways of correcting it.

This brings us back to the earlier story of the Japanese classroom. We can see that it represents quite well many of the characteristics of mathematics learning in Japanese classrooms: the whole class working together; talking but not off task; one child publicly displaying his failed solution, not to be ridiculed but rather to be corrected by his classmates. How is it possible for this scenario to occur so frequently in Japan but so little in the United States? The answer, again, lies in cultural differences. Not only are children in the United States rarely evaluated in this manner, but it is considered by many cruel to do so. If errors in mathematics are seen as due more to innate ability differences than to educable factors, then it would be regarded as cruel to publicly demonstrate a child's failings, which are no fault of his or her own. It may be that the costs of such a technique, within the context of American culture, outweigh the advantages that may derive from the analysis of incorrect problem solutions. For better or worse, American teachers feel more comfortable praising the student who performs well than discussing the errors that can occur in the course of problem solving. Unfortunately, praise is not a particularly good way to start a deep discussion of mathematics principles and procedures.

The most difficult questions, of course, remain unanswered. These are (1) which, if any, of the differences we have found cause the differences in performance? and (2) which aspects of Asian classrooms, if implemented in the context of American education, would contribute to enhancing the learning of American children? At present we cannot provide answers to these questions, and this kind of survey research will never be able to do so. What we hope to have done is to provide American educators with a picture of classroom learning that is different from our own and which thus may function to train attention back on assumptions about learning mathematics that are implicitly present in American mathematics classrooms. As White (1987) has pointed out, comparisons of education in Japan and the United States provide us not with a blueprint but rather with a mirror that can sharpen our awareness of how we educate our children and how we might do it differently. We hope that the research reported in this chapter will serve this purpose and will inspire the awareness and experimentation that will be required to understand how children in different cultures learn mathematics from classroom instruction.

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