

HOW ASIAN TEACHERS POLISH EACH LESSON TO PERFECTION

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Although there is no overall difference in intelligence, the differences in mathematical achievement of American children and their Asian counterparts are staggering.

Let us look first at the results of a study we conducted in 120 classrooms in three cities: Taipei (Taiwan); Sendai (Japan); and the Minneapolis metropolitan area. First and fifth graders from representative schools in these cities were given a test of mathematics that required computation and problem solving. Among the one hundred first-graders in the three locations who received the lowest scores, fifty-eight were American children; among the one hundred lowest-scoring fifth graders, sixty-seven were American children. Among the top one hundred first graders in mathematics, there were only fifteen American children. And only one American child appeared among the top one hundred fifth graders. The highest-scoring American classroom obtained an average score lower than that of the lowest-scoring Japanese classroom and of all but one of the twenty classrooms in Taipei. In whatever way we looked at the data, the poor performance of American children was evident.

These data are startling, but no more so than the results of a study that involved 40 first- and 40 fifth-grade classrooms in the metropolitan area of Chicago—a very representative sample of the city and the suburbs of Cook County—and twenty-two classes in each of these grades in metropolitan Beijing (China). In this study children were given a battery of mathematics tasks that included diverse problems, such as estimating the distance between a tree and a hidden treasure on a map, deciding who won a race on the basis of data in a graph, trying to explain subtraction to visiting Martians, or calculating the sum of nineteen and forty-five. There was no area in which the American children were competitive with those from China. The Chinese children's superiority appeared in complex tasks involving the application of knowledge as well as in the routines of computation. When fifth graders were asked, for example, how many members of a stamp club with twenty-four members collected only foreign stamps if five-sixths of the members did so, 59 percent of Beijing children, but only 9 percent of the Chicago children produced the correct answer. On a computation test only 2.2 percent of the Chinese fifth graders scored at or below the mean for their American counterparts. All of the twenty Chicago area schools had average scores on the fifth-grade geometry test that were below those of the Beijing schools. The results from all these tasks paint a bleak picture of American children's competencies in mathematics.

The poor performance of American students compels us to try to understand the reasons why. We have written extensively elsewhere about the cultural differences in attitudes toward learning and toward the importance of effort vs. innate ability and about the substantially greater amounts of time Japanese and Chinese students devote to academic activities in general and to the study of math in particular. Important as these factors are, they do not tell the whole story. For that we have to take a close look inside the classrooms of Japan, China, and the United States to see how mathematics is actually taught in the three cultures.

LESSONS NOT LECTURES

If we were asked briefly to characterize classes in Japan and China, we would say that they consist of coherent lessons that are presented in a thoughtful, relaxed, and nonauthoritarian manner. Teachers frequently rely on students as sources of information. Lessons are oriented toward problem solving rather than rote mastery of facts and procedures and utilize many different types of representational materials. The role assumed by the teacher is that of knowledgeable guide, rather than that of prime dispenser of information and arbiter of what is correct. There is frequent verbal interaction in the classroom as the teacher attempts to stimulate students to produce, explain, and evaluate solutions to problems. These characteristics contradict stereotypes held by most Westerners about Asian teaching practices. Lessons are not rote; they are not filled with drill. Teachers do not spend large amounts of time lecturing but attempt to lead the children in productive interactions and discussions. And the children are not the passive automata depicted in Western descriptions but active participants in the learning process.

We begin by discussing what we mean by the coherence of a lesson. One way to think of a lesson is by using the analogy of a story. A good story is highly organized; it has a beginning, a middle, and an end; and it follows a protagonist who meets challenges and resolves problems that arise along the way. Above all, a good story engages the readers' interest in a series of interconnected events, which are best understood in the context of the events that precede and follow it.

Such a concept of a lesson guides the organization of instruction in Asia. The curricula are defined in terms of coherent lessons, each carefully designed to fill a forty-to fifty-minute class period with sustained attention to the development of some concept or skill. Like a good story the lesson has an introduction, a conclusion, and a consistent theme.

We can illustrate what we are talking about with this account of a fifth-grade Japanese mathematics class:

The teacher walks in carrying a large paper bag full of clinking glass. Entering the classroom with a large paper bag is highly unusual, and by the time she has placed the bag on her desk the students are regarding her with rapt attention. What's in the bag? She begins to pull items out of the bag, placing them, one-by-one, on her desk. She removes a pitcher and a vase. A beer bottle evokes laughter and surprise. She soon has six containers lined up on her desk. The children continue to watch intently, glancing back and forth at each other as they seek to understand the purpose of this display.

The teacher looking thoughtfully at the containers, poses a question: "I wonder which one would hold the most water?" Hands go up, and the teacher calls on different students to give their guesses: "the pitcher," "the beer bottle," "the teapot." The teacher stands aside and ponders: "Some of you said one thing, others said something different. You don't agree with each other. There must be some way we can find out who is correct. How can we know who is correct?" Interest is high, and the discussion continues.

The students soon agree that to find out how much each container holds they will need to fill the containers with something. How about water? The teacher finds some buckets and sends several children out to fill them with water. When they return, the teacher says: "Now what do we do?" Again there is a discussion, and after several minutes the children decide that they will need to use a smaller container to measure how much water fits into each of the larger containers. They decide on a drinking cup, and one of the students warns that they all have to fill each cup to the same level—otherwise the measure won't be the same for all of the groups.

At this point the teacher divides the class into their groups and gives each group one of the containers and a drinking cup. Each group fills its container, counts how many cups of water it holds, and writes the result in a notebook. When all of the groups have completed the task the teacher calls on the leader of each group to report on the group's findings and notes the results on the blackboard. She has written the names of the containers in a column on the left and a scale from 1 to 6 along the bottom. Pitcher, 4.5 cups; vase, 3 cups; beer bottle, 15 cups; and so on. As each group makes its report, the teacher draws a bar representing the amount, in cups, the container holds.

Finally, the teacher returns to the question she posed at the beginning of the lesson: Which container holds the most water? She reviews how they were able to solve the problem and points out that the

answer is now contained in the bar graph on the board. She then arranges the containers on the table in order according to how much they hold and writes a rank order on each container, from 1 to 6. She ends the class with a brief review of what they have done. No definitions of ordinate and abscissa, no discussion of how to make a graph preceded the example—these all became obvious in the course of the lesson, and only at the end did the teacher mention the terms that describe the horizontal and vertical axes of the graph they had made.

With one carefully crafted problem, this Japanese teacher has guided her students to discover—and most likely to remember—several important concepts. As this article unfolds, we hope to demonstrate that this example of how well-designed Asian class lessons are is not an isolated one; to the contrary, it is the norm. And as we hope to further demonstrate, excellent class lessons do not come effortlessly or magically Asian teachers are not born great teachers; they and the lessons they develop require careful nurturing and constant refinement.

USE OF REAL-WORLD PROBLEMS AND OBJECTS

Elementary school mathematics is often defined in terms of mathematical symbols and their manipulation; for example, children must learn the place-value system of numeration and the operations for manipulating numerals to add, subtract, multiply, and divide. In addition, children must be able to apply these symbols and operations to solving problems. In order to accomplish these goals, teachers rely primarily on two powerful tools for representing mathematics: language and the manipulation of concrete objects. How effectively teachers use these forms of representation plays a critical role in determining how well children will understand mathematics.

One common function of language is in defining terms and stating rules for performing mathematical operations. A second, broader function is the use of language as a means of connecting mathematical operations to the real world of integrating what children know about mathematics. We find that American elementary school teachers are more prone to use language to define terms and state rules than are Asian teachers, who, in their efforts to make mathematics meaningful, use language to clarify different aspects of mathematics and to integrate what children know about mathematics with the demands of real-world problems. Here is an example of what we mean by a class in which the teacher defines terms and states rules:

An American teacher announces that the lesson today concerns fractions. Fractions are defined and she names the numerator and denominator “What do we call this?” she then asks. And this?” After assuring herself that the children understand the meaning of the terms, she spends the rest of the lesson teaching them to apply the rules for forming fractions.

Asian teachers tend to reverse the procedure. They focus initially on interpreting and relating a real-world problem to the quantification that is necessary for a mathematical solution and then to define terms and state rules. In the following example, a third-grade teacher in Japan was also teaching a lesson that introduced the notation system for fractions.

The lesson began with the teacher posing the question of how many liters of juice (colored water) were contained in a large beaker. “More than one liter,” answered one child. “One and a half liters,” answered another. After several children had made guesses, the teacher suggested that they pour the juice into some one-liter beakers and see. Horizontal lines on each beaker divided it into thirds. The juice filled one beaker and part of a second. The teacher pointed out that the water came up to the first line on the second beaker—only one of the three parts was full. The procedure was repeated with a second set of beakers to illustrate the concept of one-half. After stating that there had been one and one-out-of-three liters of juice in the first big beaker and one and one-out-of-two liters in the second, the teacher wrote the fractions on the board. He continued the lesson by asking the children how to represent two parts out of three, two parts out of five, and so forth. Near the end of the period he mentioned the term “fraction” for the first time and attached names to the numerator and the denominator.

He ended the lesson by summarizing how fractions can be used to represent the parts of a whole.

In the second example, the concept of fractions emerged from a meaningful experience; in the first, it was introduced initially as an abstract concept. The terms and operations in the second example flowed naturally from the teacher's questions and discussion; in the first, language was used primarily for defining and summarizing rules. Mathematics ultimately requires abstract representation, but young children understand such representation more readily if it is derived from meaningful experience than if it results from learning definitions and rules.

Asian teachers generally are more likely than American teachers to engage their students, even very young ones, in the discussion of mathematical concepts. The kind of verbal discussion we find in American classrooms is more short-answer in nature, oriented, for example, toward clarifying the correct way to implement a computational procedure.

Teachers ask questions for different reasons in the United States and in Japan. In the United States, the purpose of a question is to get an answer. In Japan, teachers pose questions to stimulate thought. A Japanese teacher considers a question to be a poor one if it elicits an immediate answer, for this indicates that students were not challenged to think. One teacher we interviewed told us of discussions she had with her fellow teachers on how to improve teaching practices. "What do you talk about?" we wondered. "A great deal of time," she reported, "is spent talking about questions we can pose to the class—which wordings work best to get students involved in thinking and discussing the material. One good question can keep a whole class going for a long time; a bad one produces little more than a simple answer."

In one memorable example recorded by our observers, a Japanese first-grade teacher began her class by posing the question to one of her students: "Would you explain the difference between what we learned in yesterday's lesson and what you came across in preparing for today's lesson?" The young student thought for a long time, but then answered the question intelligently, a performance that undoubtedly enhanced his understanding of both lessons.

CONCRETE REPRESENTATIONS

Every elementary school student in Sendai possesses a "Math Set" a box of colorful, well-designed materials for teaching mathematical concepts: tiles, clock, ruler, checkerboard, colored triangles, beads, and many other attractive objects.

In Taipei, every classroom is equipped with a similar but larger set of such objects. In Beijing where there is much less money available for purchasing such materials, teachers improvise with colored paper, wax fruit, plates, and other easily obtained objects. In all cases, these concrete objects are considered to be critically important tools for teaching mathematics, for it is through manipulating these objects that children can form important links between real-world problems and abstract mathematical notations.

American teachers are much less likely than Chinese or Japanese teachers to use concrete objects. At fifth grade, for example, Sendai teachers were nearly twice as likely to use concrete objects as the Chicago area teachers, and Taipei teachers were nearly five times as likely. There was also a subtle, but important, difference in the way Asian and American teachers used concrete objects. Japanese teachers, for example, use the items in the Math Set throughout the elementary school years and introduced small tiles in a high percentage of the lessons we observed in the first grade. American teachers seek variety and may use Popsicle sticks in one lesson, and in another marbles, Cheerios, M&Ms, checkers, poker chips, or plastic animals. The American view is that objects should be varied in order to maintain children's interest. The Asian view is that using a variety of representational materials may confuse children, and thereby make it more difficult for them to use the objects for the representation and solution of mathematics problems. Having learned to add with tiles makes multiplication easier to understand when the same tiles are used.

Through the skillful use of concrete objects, teachers are able to teach elementary school children to understand and solve problems that are not introduced in American curricula until much later. An example occurred in a fourth-grade mathematics lesson we observed in Japan. The problem the teacher posed is a difficult one for fourth graders, and its solution is generally not taught in the United States until much later. This is the problem:

There are a total of thirty-eight children in Akira's class. There are six more boys than there are girls. How many boys and how many girls are in the class?

This lesson began with a discussion of the problem and with the children proposing ways to solve it. After the discussion, the teacher handed each child two strips of paper one six units longer than the other, and told the class that the strips would be used to help them think about the problem. One strip represented the number of girls in the class and the other represented the number of boys. By lining the strips next to each other the children could see that the degree to which the longer one protruded beyond the shorter one represented 6 boys. The procedure for solving the problem then unfolded as the teacher through skillful questioning, led the children to the solution. The number of girls was found by taking the total of both strips, subtracting 6 to make the strips of equal length, and then dividing by 2. The number of boys could be found, of course, by adding 6 to the number of girls. With this concrete visual representation of the problem and careful guidance from the teacher even fourth graders were able to understand the problem and its solution.

STUDENTS CONSTRUCT MULTIPLE SOLUTIONS

A common Western stereotype is that the Asian teacher is an authoritarian purveyor of information, one who expects students to listen and memorize correct answers or correct procedures rather than to construct knowledge themselves. This may or may not be an accurate description of Asian high school teachers, but, as we have seen in previous examples, it does not describe the dozens of elementary school teachers that we have observed.

Chinese and Japanese teachers rely on students to generate ideas and evaluate the correctness of the ideas. The possibility that they will be called upon to state their own solution as well as to evaluate what another student has proposed keeps Asian students alert but this technique has two other important functions. First, it engages students in the lesson, increasing their motivation by making them feel they are participants in a group process. Second, it conveys a more realistic impression of how knowledge is acquired. Mathematics, for example, is a body of knowledge that has evolved gradually through a process of argument and proof. Learning to argue about mathematical ideas is fundamental to understanding mathematics. Chinese and Japanese children begin learning these skills in the first grade; many American elementary school students are never exposed to them.

We can illustrate the way Asian teachers use students' ideas with the following example. A fifth-grade teacher in Taiwan began her mathematics lesson by calling attention to a six-sided figure she had drawn on the blackboard. She asked the students how they might go about finding the area of the shaded region. "I don't want you to tell me what the actual area is, just tell me the approach you would use to solve the problem. Think of as many different ways as you can of ways you could determine the area that I have drawn in yellow chalk." She allowed the students several minutes to work in small groups and then called upon a child from each group to describe the group's solution. After each proposal, many of which were quite complex, the teacher asked members of the other groups whether the procedure described could yield a correct answer. After several different procedures had been suggested, the teacher moved on to a second problem with a different embedded figure and repeated the process. Neither teacher nor students actually carried out a solution to the problem until all of the alternative solutions had been discussed. The lesson ended with the teacher affirming the importance of coming up with multiple solutions. "After all," she said, "we face many problems every day in the real world. We have to remember that there is not only one way we can solve each problem."

American teachers are less likely to give students opportunities to respond at such length. Although a great deal of interaction appears to occur in American classrooms—with teachers and students posing questions and giving answers—American teachers generally pose questions that are answerable with a yes or no or with a short phrase. They seek a correct answer and continue calling on students until one produces it. “Since we can’t subtract 8 from 6,” says an American teacher, “we have to -. what?” Hands go up, the teacher calls on a girl who says “Borrow.” “Correct,” the teacher replies. This kind of interchange does not establish the student as a valid source of information, for the final arbiter of the correctness of the student’s opinions is still the teacher. The situation is very different in Asian classrooms, where children are likely to be asked to explain their answers and other children are then called upon to evaluate their correctness.

Clear evidence of these differing beliefs about the roles of students and teachers appears in the observations of how teachers evaluate students’ responses. The most frequent form of evaluation used by American teachers was praise, a technique that was rarely used in either Taiwan or Japan. In Japan, evaluation most frequently took the form of a discussion of children’s errors.

Praise serves to cut off discussion and to highlight the teacher’s role as the authority. It also encourages children to be satisfied with their performance rather than informing them about where they need improvement. Discussing errors, on the other hand, encourages argument and justification and involves students in the exciting quest of assessing the strengths and weaknesses of the various alternative solutions that have been proposed.

Why are American teachers often reluctant to encourage students to participate at greater length during mathematics lessons? One possibility is that they feel insecure about the depth of their own mathematical training. Placing more emphasis on students’ explanations necessarily requires teachers to relinquish some control over the direction the lesson will take. This can be a frightening prospect to a teacher who is unprepared to evaluate the validity of novel ideas that students inevitably propose.

USING ERRORS EFFECTIVELY

We have been struck by the different reactions of Asian and American teachers to children’s errors. For Americans, errors tend to be interpreted as an indication of failure in learning the lesson. For Chinese and Japanese, they are an index of what still needs to be learned. These divergent interpretations result in very different reactions to the display of errors—embarrassment on the part of the American children, calm acceptance by Asian children. They also result in differences in the manner in which teachers utilize errors as effective means of instruction.

We visited a fifth-grade classroom in Japan the first day the teacher introduced the problem of adding fractions with unequal denominators. The problem was a simple one: adding one-third and one-half. The children were told to solve the problem and that the class would then review the different solutions.

After everyone appeared to have completed the task, the teacher called on one of the students to give his answer and to explain his solution. “The answer is two-fifths,” he stated. Pointing first to the numerators and then to the denominators, he explained: “One plus one is two; three plus two is five. The answer is two-fifths.” Without comment, the teacher asked another boy for his solution. “Two point one plus three point one, when changed into a fraction adds up to two-fifths.” The children in the classroom looked puzzled. The teacher, unperturbed, asked a third student for her solution. “The answer is five-sixths.” The student went on to explain how she had found the common denominator changed the fractions so that each had this denominator and then added them.

The teacher returned to the first solution. “How many of you think this solution is correct. Most agreed that it was not. She used the opportunity to direct the children’s attention to reasons why the solution was incorrect. Which is larger two-fifths or one-half?” The class agreed that it was one-half. “It is strange, isn’t it that you could add a number to one-half and get a number that is smaller than one-

half?" She went on to explain how the procedure the child used would result in the odd situation when, when one-half was added to one-half, the answer yielded is one-half. In a similarly careful, interactive manner, she discussed how the second boy had confused fractions with decimals to come up with his surprising answer. Rather than ignoring the incorrect solutions and concentrating her attention on the correct solution, the teacher capitalized on the errors the children made in order to dispel two common misperceptions about fractions.

We have not observed American teachers responding to children's errors so inventively. Perhaps because of the strong influence of behavioristic teaching that conditions should be arranged so that the learner avoids errors and makes only a reinforceable response, American teachers place little emphasis on the constructive use of errors as a teaching technique. It seems likely, however that learning about what is wrong may hasten children's understanding of why the correct procedures are appropriate.