Reflections on Math Reforms in the U.S.

A CROSS-NATIONAL PERSPECTIVE

Understanding how various aspects of mathematics education work together is necessary if reform efforts are to succeed, Ms. Newton argues. She compares U.S. and Chinese mathematics education to provide perspectives that might further such understanding.

BY XIAOXIA NEWTON

IN TRADITIONAL Chinese medicine, a key maxim is "Zhi Bing Yao Zhi Gen," which literally means, "To cure a disease (you) must cure the underlying cause." I am reminded of this principle whenever I reflect on K-12 math education reform in the U.S. President Bush's 2006 State of the Union Address prompted yet another wave of debate on what actions the government should take in order to improve math and science education so that the U.S. can sustain its economic competitiveness internationally. What has not been brought to the forefront, however, is that cultural beliefs about mathematics and how it should be taught will profoundly influence how reform efforts, such as new curricula or teaching methods, will work themselves out in practice.

As someone who was educated in mainland China and has subsequently studied math teaching and learning in the U.S., I have been struck by the many differences in the beliefs surrounding math instruction between the two countries. I hope my reflections on what I have seen can help highlight some key issues identified in the mathematics re-

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form literature and provide a lens for examining how mathematics instruction functions in the U.S. and China.

CULTURAL BELIEFS AND ATTITUDES

When it comes to attitudes about who can learn math, it is common in the U.S. to give more weight to ability than to effort.[1] It is widely acceptable for anyone in the U.S. to say, "I just can't do math." Since ability is widely believed to be fixed and uncontrollable, attributing success or failure to high or low ability has an important impact on motivation. Presumably, inasmuch as ability is seen as fixed and not subject to individual control, ascribing failure to low ability leads students to give up. Effort, on the other hand, is clearly within an individual's control, and so ascribing success in learning mathematics to effort leads students to sustain their hope and increase their persistence.

Unlike the U.S., some societies put greater emphasis on effort than on ability.[2] That is certainly the case with China, as I can attest. Though English was the only school subject that I was passionate about when growing up, I was nonetheless pushed by my engineer father into being a math and science major in high school. He often said, "If you aren't good at math, physics, and chemistry, how can you make a living? What are you going to do?" My father's attitude toward the importance of math and science was typical of the value placed on such subjects by Chinese society in general. In my high school, only about 15% of the students were on the liberal arts and humanities track, while the rest of us pursued math and science. Persistent effort was highly regarded and encouraged. Our teachers liked to emphasize that, if you do not think you can grasp a concept as fast as others, then you must work harder or start earlier (e.g., preview the textbook before the class when a new concept will be taught).

People's beliefs about what mathematics is also seem to differ. In Western thinking, mathematics is often described as the most "certain" branch of human knowledge. In mathematics, people in the West will say, it is easy to distinguish "right" from "wrong."[3] Such a heavy emphasis on truth and correctness in mathematics contrasts sharply with how mathematics is treated in some high-achieving Asian countries. For instance, the Third International Mathematics and Science Study (TIMSS) revealed that Japanese math teachers emphasize developing conceptual understanding rather than simply obtaining correct answers.[4] The Singapore math curriculum at both the elementary and secondary levels clearly specifies that the essence of school mathematics is problem solving.[5] Other comparative studies involving Japan, Hong Kong, Taiwan, mainland China, England, and the U.S. also suggest that Asian teachers ask significantly more questions about conceptual knowledge and problem-solving strategies than do U.S. teachers. In addition, Chinese teachers place questions in a concrete context significantly more often than do U.S. teachers.[6]

In my own experience learning math, my teachers always emphasized that there is more than one way to solve a problem. Each way works better under certain conditions, and the more you understand this, the more flexibility you have in choosing how to approach a problem. My teachers also stressed that the key to solving problems is to understand why you take a particular approach, so that you can then use that understanding to "solve a thousand similar problems."

In contrast to such an emphasis on flexibility and creativity in approaching problem solving in mathematics, the overemphasis in the U.S. on what's "right" and what's "wrong" means that teachers have difficulty creating authentic conversations with students about mathematics. In my own observations of U.S. classrooms, I frequently find both teachers and students to be strictly concerned with finding the right answer. Sometimes, both the teacher and the students are satisfied with a right answer — even when the students cannot explain how to obtain it or why the approach worked.[7]

Apart from problems associated with focusing on high ability versus low ability and rightness versus wrongness, two of the most important components of mathematics teaching and learning are also problematic: namely, curriculum, which is related to opportunities to learn math content, and assessment, which is the tool used to hold students, teachers, and schools accountable.

FRAGMENTED AND REPETITIVE CURRICULUM

Curriculum serves as the foundation for learning the knowledge base of school subjects. China approaches the design of school subjects in a coherent and progressive manner, with little repetition of content materials. In China, the focus areas of study in elementary schools are literacy and arithmetic, enriched with moral education, music, art, and physical education courses.[8] Each subject is taught by a teacher who is specially trained for teaching that subject — even in the elementary grades.

In the first year of middle school, other courses are added to the curriculum, including political science, biology, English, history, and geography. Mathematics at this level (i.e., at the beginning of the sixth grade) is divided into algebra and geometry, which all students take simultaneously from this grade and on. Physics is added in seventh grade, followed by chemistry in the eighth grade. So by the beginning of eighth grade, students are taking Chinese literacy/literature, English, political science, history, geography, biology, mathematics (algebra and geometry), physics, chemistry, and physical education courses. Each subject is still taught by a teacher who is specially trained for teaching that subject. Music and art become extracurricular activities at this stage.

The curricular design for the academic subjects introduced in higher grades follows the same logic as the design for reading and arithmetic at the elementary level: a coherent and progressive approach that goes from simple to complex topics within a discipline. At the beginning of the second year of high school (equivalent to the U.S. 10th grade), students choose one of two tracks for further education: liberal arts (where biology, physics, and chemistry courses are dropped) versus math and science (where geography, by this grade focused on geology, and history courses are dropped). Students on both tracks continue to take Chinese literacy/literature, mathematics, English, and political science courses. At both the elementary and secondary levels, students take a combination of different courses on different days, which makes it possible to take a wider variety of courses at once.

In contrast to the Chinese curriculum, the U.S. mathematics curriculum is broad but superficial, and it is fragmented rather than coherent. In light of the TIMSS curriculum studies, many observers have characterized the U.S. mathematics curriculum as "a mile wide and an inch deep." Furthermore, the inherent logical structure of mathematics (i.e., the hierarchy and connectedness of different concepts and their applications at different levels of sophistication) is obscured by the continual jumping back and forth between basic and advanced topics that is typical of the U.S. curriculum.[9] Such a curriculum design fails to make the coherence and connectedness among different mathematical concepts and topics transparent to students — or even to teachers who are working with the curriculum. One likely consequence is the fragmentation of mathematical knowledge that students and teachers acquire.

ACCOUNTABILITY AND MULTIPLE-CHOICE ASSESSMENTS

Consistent with the spirit of a coherent and progressive approach to curricular design, the accountability system in China is set up with the goal of preparing students at lower grades for learning the content at higher grades in each subject area and ultimately for taking the entrance exam to colleges and universities.[10] The entrance exam, which is the only high-stakes exam administered at the end of students' senior year, is a multi-day, multi-discipline exam that consists of mostly constructed-response items. There is no way to simply guess the right answers, and students who wish to score well on the exam need to understand the content.

The college entrance exam sets the tone for the school assessment system all the way from senior high school down to the earliest grades. Schoolwide and grade-level midterms or finals, which are written by the teachers of specific subject areas for specific grades, mirror the college entrance exam in terms of test format (mostly constructed-response items) and emphasis (understanding content). Students must demonstrate their understanding by solving mathematical problems, working through proofs, etc. Such an accountability system pushes teachers to teach students for understanding.

In contrast to the Chinese accountability system, the accountability system in the U.S. is largely based on statewide, paper-and-pencil, often multiple-choice assessments. Though state frameworks and content standards for K-12 schools put equal emphasis on computational skills, problem solving, and conceptual understanding, such a balance is not reflected in the format and focus of most high-stakes assessments in the U.S. William Schmidt described the distorting impact of these tests in an interview on the PBS series "Frontline":

> What we found is they tend to test what's on the simple end of the spectrum in math and science. The more complex stuff, which the reform advocates push, is never tested. Now, that's really a critical issue, because teachers, knowing that their kids will be assessed accordingly and their jobs may be dependent on how well their students do, they'll go with what's on the test. And that pushes them in the direction, in mathematics, of more simple computation-type things and leaves out the more complex mathematics that's comparable to what other countries do.[11]

INSTITUTIONAL DESIGN VERSUS REFORM EXPECTATIONS

On top of the problems posed for the U.S. by the cultural beliefs surrounding mathematics and by the entrenched curriculum and assessment system, three distinctive aspects of the way the K-12 education system functions in the U.S. stand in the way of schools' efforts to fundamentally improve mathematics teaching and learning systemwide.

First, elementary teachers are typically expected to master and teach multiple subjects in the U.S. In contrast, Chinese teachers at both elementary and secondary levels teach only the subject for which they are specially trained. For someone like me, who grew up in a system where different subject areas are taught by specially trained teachers, the expectation that one person would teach all the things kids need to learn in reading/language arts, mathematics, science, social science, and so on was surprising, not to say incomprehensible. This generalist approach to elementary education within the U.S. gives the impression that elementary mathematics (or perhaps any subject) is perceived as basic, superficial, commonly understood, and repetitive.[12] By this logic, any educated person should be able to teach elementary mathematical topics.

Such an assumption carries a heavy cost, though, because the elementary years are a most critical stage, when students are building a solid foundation for later schooling in the full range of subjects. Without a solid foundation, the gaps in knowledge that are formed in the early grades can expand as students move from grade to grade. Indeed, a lot of problems we see in high schools seem to stem from the poor foundational skills students acquired in the early elementary grades.

The typical secondary math teacher in the U.S. has only one so-called conference period when he or she is alone. During the rest of the day (usually five or six class periods), the teacher spends most of the time standing in front of the classroom, teaching.

Second, U.S. teachers have little time for daily preparation, reflection, and sharing with colleagues, whereas Chinese teachers have a lot. Secondary math teachers in the U.S., even though they teach only math, are nonetheless handicapped by the limited amount of time they have to devote to their own learning. The typical secondary math teacher in the U.S. has only one so-called conference period when he or she is alone. During the rest of the day (usually five or six class periods), the teacher spends most of the time standing in front of the classroom, teaching.

The allocation of teachers' professional time in the U.S. seems to imply that, once teachers graduate and "have a credential," they are done with learning and know everything they need in order to teach. Otherwise, one would expect that significant time for such activities as lesson planning, collaboration with colleagues, and professional development would be built into the weekly schedules of all teachers. Teachers in other countries, such as China, typically spend about 40% of their daily time in the classroom with students. When not teaching, they spend time doing other important instruction-related activities, such as grading student work, preparing lessons, studying teaching materials, and interacting with colleagues.[13]

Finally, U.S. teachers are expected to work in isolation, whereas Chinese teachers are organized in "Jiao Yan Zu," that is, "teaching research groups."[14] Though I have not taught elementary or secondary mathematics, such "teaching research groups" are familiar to me. While studying for my master's degree at Tshinghua University in Beijing, I taught one section of English to a group of freshman engineering majors. The teachers of the other three sections of the course and I each had a mentor. In addition, all four of us participated in the weekly, hourlong meetings where all English teachers who were teaching the same level course met formally to plan the following week's lesson. The typical setup in U.S. schools, which places one elementary teacher with the same group of kids in a classroom all day, stems from a deep cultural norm that regards successful teaching as a reflection of individual ability rather than a set of learned professional competencies acquired over the course of a career.[15] And it is a recipe for isolation.

CONCLUDING REMARKS AND SUGGESTIONS

Tomorrow's math teachers will emerge from the ranks of today's children. Unless we provide children with a rich experience in mathematics as they progress through the school system, we are likely to repeat the cycle of poor learning experiences, inadequate foundational knowledge and skills for teaching, and weak educational outcomes in mathematics. My aim here is not to trumpet the superiority of the Chinese system over the U.S. system. Rather, I am attempting to highlight the Chinese emphasis on thinking systematically about teaching, curriculum, and assessments. How these aspects of mathematics education work together as a system must be an important consideration if any reform effort in the U.S. is to succeed. Changing individual elements of the system may be ineffective if the rest of the system is not adjusted accordingly.

In an effort to help us think about reforming and improving K-12 math education in the U.S., I close with the following suggestions, some of which may well strike many readers as culturally out of place.

• The K-5 institutional design must free elementary teachers from being generalists. They need to become experts in specific subjects and will need opportunities to practice teaching a single-subject curriculum, to reflect, and to continue developing their content knowledge.

• The K-12 institutional design must free both elementary and secondary teachers from spending every second of their time teaching. The system must build in time for other equally important activities, such as lesson planning, collaborating with colleagues, grading student work, and providing high-quality feedback to students. The allocation of time to teaching and to other activities must reflect the complex demands of teaching.

• The K-12 math curriculum must be designed to respect both the disciplinary structure of mathematics and the cognitive development of children. For example, the Singapore math curriculum — much praised and much maligned by contending factions in U.S. math education reform — is an excellent example of a curriculum in which the structure and hierarchy of different mathematical topics are maintained. And it is written in English.

• The accountability system must reflect the purpose of education and be reasonable. For example, elementary schools are accountable for adequately preparing students for middle school, while middle schools are accountable for adequately preparing students for high school, and high schools are accountable for graduating students who possess adequate literary and quantitative skills to enable them to pursue different educational and career paths and to be productive citizens.

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8. Moral education typically combines the teaching of Confucian thought and Communist ideology.

9. William Schmidt, "The Role of Curriculum," *American Educator*, Fall 2005, available at www.aft.org/pubs-reports/american_educator/issues/fall2005/schmidt.htm.

10. In China, it is not uncommon for postsecondary institutions to be involved in writing college entrance exams.

11. William Schmidt, interview, "Testing Our Schools," "Frontline," PBS, 2002.

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