Math and Science Education In a Global Age:

What the U.S. Can Learn from China

Asia Society

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PREFACE AND ACKNOWLEDGEMENTS

Over the past few years, Asia Society has led delegations of American education leaders to China and hosted Chinese leaders in the United States in an effort to deepen knowledge of each other's successes and challenges, and to strengthen educational cooperation between the two countries.

Two delegations, in 2003 and 2005, visited a wide range of schools and universities in China at the invitation of the Chinese Ministry of Education. In 2004, a Chinese delegation of directors of education from seven provinces, led by Chinese Vice Minister of Education Zhang Xinsheng, visited the United States and participated in meetings of the Council of Chief State School Officers, Education Commission of the States, The College Board, and Asia Society. Several important initiatives have resulted from these exchanges, including the creation of a new Advanced Placement Course and Examination in Chinese (Mandarin) Language and Culture by The College Board, partnerships between American states and Chinese provinces to link schools and teachers, and joint initiatives to increase the number of American schools that teach Chinese.

In the spirit of greater collaboration and given the need for qualified American graduates in science, technology, engineering, and mathematics, in 2005 Asia Society convened a meeting of top American and Chinese math and science education experts in Denver, Colorado. This report examines the meeting's main areas of discussion and lays out areas for ongoing cooperation.

On behalf of Asia Society, I would like to thank the Ministry of Education of the People's Republic of China for co-organizing the Forum. Chen Xiaoya, Vice Minister for Education in China and Piedad Robertson, President of the Education Commission of the States (which hosted the delegation in Denver), both took time to make informative opening remarks. The Forum co-chairs were Dr. Yang Jin, Deputy Director-General at the Chinese Department of Basic Education, and Dr. Susan Sclafani, then Assistant Secretary for the Office of Vocational and Adult Education at the U.S. Department of Education. We are deeply grateful to Senta Raizen, Director of the National Center for Improving Science Education, for preparing the draft report and lending to this endeavor her expertise in science education in the United States and internationally. Fruitful discussion and groundwork for future collaboration would not have been possible without the Forum's participants who came to Denver with open minds and a willingness to forge important new ties with their peers domestically and abroad. They also made valuable comments on the draft report. Marta Castaing and Weiwei Wang on Asia Society's staff researched background materials and provided logistical support for the Forum.

Finally, Asia Society is grateful to the Freeman, Ford, Starr, Bill & Melinda Gates, and Goldman Sachs foundations for their generous support of Asia Society's education work.

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May 2006

EXECUTIVE SUMMARY

In an era when technology and the rapid flow of information dominate every major area of economic growth, innovation and excellence in mathematics and science are integral to a nation's long-term success. While American scientific research is admired around the world, there are grave concerns in the United States about the quality of math and science education in American schools. International comparisons of student achievement show that U.S. K–12 students' performance in science and mathematics is mediocre compared with students in other countries, especially those in East Asia. And while such comparisons used to be matters for mainly academic discussion, in a global economy it is no longer enough for a state or school district to compare itself with the state or district next door; they need to compare themselves against world standards.

U.S. policymakers and business leaders are sounding the call for greatly increased investment in K–12 math and science education, but increased funding in K–12 education over the past two decades has not yielded significant gains in student achievement. There is therefore growing interest in learning from education systems in other countries that produce higher student achievement in math and science.

Given the common challenges posed by globalization, many nations also face capacity-building issues in workforce development and education. In 2005, Asia Society and the Ministry of Education of the People's Republic of China convened the U.S.-China Education Leaders Forum on Math and Science Education in Denver, Colorado. The purpose of the Forum was to deepen knowledge of the two education systems and to develop a set of ideas as to how the two countries could learn from each others' strengths and challenges in mathematics and science education. This report summarizes the discussion at the Forum as well as related research on Asian achievement in math and science to make these ideas available to a wider audience.

Learning from China

With 367 million people below the age of 18, China runs the world's largest educational system, serving 20 percent of the world's students with only 2 percent of the world's educational resources. China has made significant progress over the past two decades in making nine years of basic education nearly universal and has set a goal of extending that to twelve years by 2015. Although it still faces enormous challenges in extending education to underserved populations in rural areas, math and science education in China's cities, like that in other East Asian nations, is of high quality and has lessons for the U.S. Among these are:

National Standards and Aligned Instruction. In both science and mathematics, China has national standards for what is to be taught. Textbooks, materials, teacher preparation, and professional development are all clearly aligned to these standards. By contrast, in the U.S., there is a great deal of variation in the rigor and quality of standards between states and between school districts, and because textbooks have to meet the standards of many states, they are voluminous and tend to cover many concepts superficially. Furthermore, math and science courses for prospective teachers in universities are often not related to what they will teach in schools.

Curriculum Design. The curriculum in China focuses on building strong foundational knowledge and mastery of core concepts. Biology, chemistry, and physics as well as algebra and geometry are mandatory for completion of high school. This strong core curriculum contrasts with the approach of U.S. secondary schools where students are allowed to choose among different levels of courses and, ultimately, to opt out of more advanced learning. (In 2000, nearly 40 percent of high schools students had not taken any coursework in science more challenging than general biology.)

Rigorous and Ongoing Preparation of Science and Math Teachers. Far higher proportions of science and math teachers in East Asia have degrees in their discipline than their U.S. counterparts. Fewer than 60 percent of U.S. eighth-grade science teachers have majors in a science discipline and only 48 percent of eighth-grade math teachers have a math major. In addition, Chinese schools do not expect a single elementary school teacher to teach all subjects; specialist science teachers are employed as early as third grade. A tradition of mentoring by master teachers and weekly professional development in schools continually improves teacher performance.

Examinations. Chinese education is examination-driven. Math and science scores attained in the university entrance examination system count highly in differentiating among students seeking college admission. Therefore these subjects command major emphasis in the curriculum and in student effort. This systemic emphasis on math and science has many advantages; for example, girls as well as boys do well in science. But as the United States moves toward high-stakes testing, there are lessons, both positive and negative, to be learned from the Chinese experience.

Time and Academic Focus. Reflecting the strong cultural value placed on education, Chinese schools are more academically focused than most American schools, which serve a variety of functions in the community. The Chinese school year is also a full month longer at the secondary level than the American school year. Overall, Chinese students spend twice as many hours studying as their U.S. peers—in school and outside of school in homework, extra tutoring, and studying for examinations. Students are highly motivated to succeed in order to participate in the expanding opportunities that are open to those with a good education.

Common Challenges and Areas of Potential Collaboration

In many respects, the U.S. and Chinese educational systems are mirror images of each other. And while the U.S. has much to learn from China about how to get large numbers of students to truly excel in math and science, Chinese educators admire and seek to learn from the greater choice, second-chance opportunities, and inquiry-oriented teaching methods that characterize American schools. Both countries identified some common challenges in producing scientifically literate populations where international exchange can broaden the conception of educational solutions. These include:

Curriculum Design and Assessment. A comparison of each country's curriculum standards and textbooks with respect to key concepts, level, focus, and alignment would provide valuable insights into whether the competencies students are expected to acquire are truly world-class and relevant to twenty-first–century science. In addition, since examinations and assessment have great influence on what science and math is studied, and are increasingly being used by policymakers to drive educational systems change, understanding the advantages and disadvantages of each country's examination and assessment systems was assigned a high priority.

Teacher Preparation and Professional Development. Expertise in mathematics and science entails a firm grasp of concepts and the ability to apply these in new situations. While there is a great deal of research on what constitutes effective teaching methods for optimum student achievement, neither country's education system fully reflects these practices. Thus both countries have enormous needs for training teachers already in the classroom. In the U.S., systems need to be found to improve teacher content knowledge and instructional strategies on a large scale, going beyond the teachers who typically volunteer for such training. China's system of new teacher induction and ongoing professional development through master teachers provides interesting examples of both classroom-based and distance education forms. China's teachers, in turn, need help in transforming their instructional strategies from the didactic rote memorization tradition toward greater stress on active participation and inquiry by students and development of critical thinking skills. The U.S. has significant strength in these areas that could be shared.

Using Information Technology Effectively. In the wake of the worldwide technology revolution, a great deal is being invested in infrastructure—wiring schools and improving access to computers. Research shows that this investment has typically had little impact on student achievement. Yet, there is enormous potential for using technology for more effective science learning if the capacities of the medium are truly utilized. For example, virtual courses can bring advanced science to underserved students and teachers; simulations can teach complex phenomena; and international joint science projects between students can enhance scientific and technological skills while also teaching critical global competencies.

Reaching Gifted and Underserved Populations. Both countries have sizable student populations that are not benefiting sufficiently from the current system of mathematics and science education. Sharing experiences with effective ways to reach rural and minority populations was seen as a key area of joint comparative work. In addition, in an age that puts a premium on the most talented scientists, there is concern in the United States that gifted students are being neglected. In this respect, China's "key" high schools and residential schools would be interesting for the United States to examine.

All these issues, which are spelled out in greater detail in this report, could be pursued through comparative research, through mutual observation of practice, through linkages of teacher training institutions, and through joint development projects.

Educational innovations are taking hold around the world. Educational ideas from one setting may not be totally applicable in others, but they provide useful ideas about potential solutions. Such international benchmarking of best practices is no longer just a pursuit for a small group of interested researchers. In a global age, benchmarking to world standards is becoming a competitive necessity. And the process of helping to improve education around the world is also an increasingly important part of U.S. international engagement.

INTRODUCTION

In an era where technology and the rapid flow of information dominate every major area of economic growth worldwide, innovation and excellence in mathematics and science are integral to any nation's long-term success. While American scientific research is widely admired, there are grave concerns about the quality of math and science education in the United States. International comparisons of student achievement show that the performance of K–12 students is mediocre compared with that of students in other countries, especially those in East Asia. In a global economy, it is no longer enough for a state or school district to compare itself with the state or district next door. They need to compare themselves against world standards.

Business leaders and policymakers are increasingly sounding the call for greater investment in math and science education, but increased funding in K–12 education over the past two decades has not yielded great gains in achievement. There is therefore increased interest in learning from education systems in other countries that have higher achievement in math and science.

Given the common challenges posed by globalization, many nations face similar or complementary capacity-building issues in workforce development and education. The U.S.-China Education Leaders Forum on Math and Science Education, held in 2005 at the ECS Annual Meeting in Denver, Colorado, presented an opportunity to share challenges and strategies for educational success within two different national contexts, and to draw lessons from each system's strengths for future reforms. The Forum was organized by the Asia Society and the Ministry of Education of the People's Republic of China, in conjunction with the Education Commission of the States.

The purpose of the Forum was to deepen knowledge of the two education systems among Chinese and American education leaders, and to develop a set of ideas for how the two countries could learn from each country's strengths and challenges in mathematics and science education at the primary and secondary levels. Participants considered the following questions:

- **What are the strengths and weaknesses in current science and mathematics standards, curriculum design, and assessments in China and the United States?**
- **What forms of instruction lead to a firm grasp of central math and science concepts and the ability to apply them in new situations? What are the best practices in teacher preparation and professional development that produce this level of understanding?**
- **What are the most promising ways in which information and communication technologies can facilitate math and science education?**
- **What are the most promising areas and possible mechanisms for collaboration between China and the United States?**

Senior education officials from both countries opened the meeting by presenting what they saw to be the most important challenges in primary and secondary education, particularly with respect to teaching of mathematics and science.

Susan Sclafani, then U.S. Assistant Secretary of Education for the Office of Vocational and Adult Education, discussed some of the major challenges facing the American education system. While spending in education has grown considerably, overall achievement levels are not increasing. The U.S. school system took shape at a time when there were many opportunities for unskilled workers; today only 10 percent of American jobs will be available for unskilled workers, leaving American schools struggling to educate students for a new, fast-changing knowledge economy. Many students do not have the basic math or science skills now required for college and the workplace, eventually requiring remedial education or alternative paths to earning their high school diploma. Teachers are largely unprepared to teach for this new economy; they themselves lack the education or training to teach higher concepts. Most top math and science students in colleges or universities go into the private sector or are discouraged outright from going into education. Nationwide, the curriculum is very uneven, often circling back through topics over a student's course of study, without teaching basic concepts to mastery. The federal No Child Left Behind Act, which calls for renewed accountability standards, an emphasis on evidence-based practice, greater local control, and increased opportunities for school choice, is one response to these challenges. However, although all these problems are widely discussed, the United States is not taking action fast enough to keep up with the rapid changes in the global economy.

China is running the world's largest education system, serving 20 percent of the world's young people, but accounting for only 2 percent of the total world expenditure on primary and secondary education.

Chen Xiaoya, Vice Minister for Basic Education at the Chinese Ministry of Education, introduced the meeting participants to China's educational successes and challenges by painting a picture of scale and vision. Her address described the major accomplishments of China over the past two decades in extending nine years of basic education to most of the country and virtually eliminating illiteracy among young and middle-aged adults. With 367 million people below the age of 18, China runs the world's largest educational system, serving 20 percent of the world's students with only 2 percent of the world's educational resources. China is now focused on addressing the large gap between urban and rural areas by making basic education universal through boarding schools, student subsidies, and the use of distance education technologies to reach students in rural areas. Saying that the world today demanded a global vision with global communication skills to live and work together, she welcomed the opportunity for education to be a bridge of cooperation and communication between the United States and China.

Participants went on to discuss specific strategies and challenges in mathematics and science education in each country, assessing the similarities and differences among the issues in education approaches and policy. Participants then identified a number of areas of mutual interest where cooperation by educators and researchers from both countries would hold promise of improving students' understanding of science.

This report, which is based on the background materials prepared for the Forum and the presentations and discussion at the meeting, is intended to make the ideas available for discussion by a wider audience.

UNITED STATES AND CHINA: CONTRASTING SYSTEMS

Forum participants reviewed some of the major areas of difference between the two countries' education systems. These include:

- **population size**
- **years of schooling**
- **standards and alignment**
- **teaching materials and computer access**
- **mathematics and science curricula**
- **preparation of science and mathematics teachers**
- **teaching methods**
- **testing and examination systems**
- **time on task and academic focus**
- **student achievement**

Population Size

Perhaps the most startling contrast between the two countries' education systems is size. A few numbers tell the tale (Chen 2005). The population of China is 1.3 billion, one-fifth of the world's population. Of this total, 367 million are below the age of 18—roughly five times as many as the 73 million youth aged 18 and under in the United States. This population of Chinese young people includes 214 million primary and secondary students, compared to 48 million such American students. Chinese ministry officials put this another way: China is running the world's largest education system, serving 20 percent of the world's young people, but accounting for only 2 percent of the total world expenditure on primary and secondary education (see Figure 1).

Years of Schooling

In 1986, China legislated nine years of compulsory schooling for all: six years of primary school and three years of lower secondary school. In addition, three years of high school are widely available in large cities, but not compulsory. In the United States, twelve years of elementary and secondary school (from ages 6–18) generally are compulsory, although some percentage of students in grades 9–12 drop out before high school graduation. In both countries, completion rates of twelve years of schooling vary by population group: in China, high school attendance rates are much lower in the largely rural western provinces (see Figure 2). In fact, even the compulsory nine years of schooling has not yet become a reality in those regions.

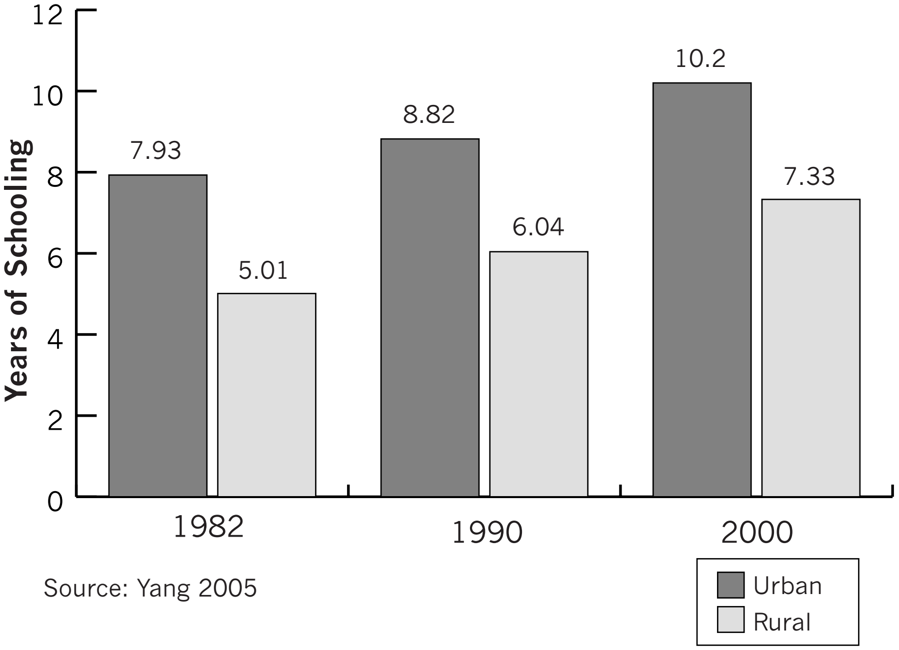
In China nationwide, total enrollment in high school is about 50 percent of the eligible population. On the other hand, in the United States, the high school graduation rate varies by ethnic group: it is considerably higher for

Figure 1: Data on Chinese Education System (2004)

	Number of Schools	Number of Teaching Staff	Number of Students	Gross Rate of Enrollment
Higher Education	3,423	970,506	18,352,821	19%
High School	31,493	1,920,894	36,076,284	47.6%
Middle	63,757	3,500,464	65,762,936	94.1%
Primary	394,183	5,628,860	112,462,256	106.6%
Preschool	117,899	656,083	20,894,002	40.8%

Source: Yang, 2005

Figure 2: Average Schooling Years in China of Urban and Rural Inhabitants



Source: Yang 2005

white students (72 percent) than for Hispanic and African-American students (52 percent and 51 percent, respectively) (Sclafani 2005). But the American system of education is relatively fluid. For example, a number of young adults in the United States obtain a GED (General Educational Development) diploma some years after dropping out of school, or they enroll in any number of community colleges (two-year post-secondary institutions) without first obtaining high school graduation certificates—two of the several alternative educational pathways available in the United States.

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> In the United States, there is a great deal of variation in the rigor and quality of standards among states.

Standards and Alignment

In both science and mathematics, China has national standards for what is to be taught at each of the three levels of schooling. While these standards are revised from time to time, they spell out in some detail the topics that students are expected to master (Wang 2005). For example, the current standards in mathematics call for ten topics to be learned during the first stage (grades 1–3): five concerning numbers and operations, five concerning geometry. Approximately the same number of topics in each area are to be mastered in the succeeding two stages of compulsory schooling (grades 4–6, grades 7–9) at increasingly complex and sophisticated levels, though the number of geometry topics increases for grades 7–9, and reasoning and proof are added.

By contrast, at the national level, the United States has voluntary standards in both science and mathematics. Even though these standards have been prepared by prestigious bodies (American Association for the Advancement of Science, 1993; National Research Council, 1996; National Council of Teachers of Mathematics, 2000) and have served as the basis for most state curriculum standards, there is a great deal of variation in rigor and quality among these state standards, and even more so from district to district (Porter 2005). Ginsburg et al. (2005) contrasted the average number of topics per grade in the mathematics frameworks of Singapore with frameworks from several states and found that some states included twice as many topics as Singapore.

Many policy analysts in the United States have concluded that the lack of national standards is one of the reasons that students in Asian and some European countries tend to outperform their American peers in science and mathematics. For example, a well-known scholar and former U.S. government official recently urged the adoption of national standards, national tests, and a national curriculum (Ravitch 2005), as have a former governor and a former corporate officer (Olson 2005). However, others question this conclusion in view of the fact that there are counter examples of countries that have a centralized curriculum but whose students do not exhibit high performance in international comparative tests (Wang and Lin 2005).

In China all textbooks and other teaching materials must meet the national standards.

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U.S. textbooks are voluminous because they must meet the standards of many states.

Teaching Materials and Computer Access

Recently, the Chinese Education Ministry authorized the development of several alternative (rather than just one) sets of text materials for the required mathematics syllabus to allow for more flexibility in teaching approaches. However, in China all textbooks and other teaching materials must meet the national standards set forth by the government. In the United States, the development of curriculum materials is left to the private sector, and textbook adoption is left to local committees of teachers, sometimes based on a state-approved list of materials (depending on legislative requirements of individual states). Textbook publishers generally claim that their materials are based on the national voluntary standards, but as it is in their interest to maximize sales, the materials tend to be inclusive, that is, addressing the standards of as many states as possible. The standards of the most populous states however, such as Texas, California, and Florida, tend to be highly influential. The resulting textbooks, particularly those for secondary science courses, often lack coherence and are so voluminous that teachers generally select which chapters to teach, often covering no more than a third of the topics included in the textbook they are using. This leads to further fracturing of the curriculum across the more than 15,000 school districts responsible for providing elementary and secondary education in the United States.

Students' access to computers varies but has grown in most countries. For example, nearly 70 percent of U.S. fourth-graders have access to computers for their classes (Ginsburg et al. 2005) compared to fourth-graders in Chinese Taipei, where only some 15 percent have access. In Hong Kong nearly 65 percent have access and in Japan access is nearly universal—almost 90 percent. In China, access to computers varies widely between rural and urban areas. In 2003, the student-to-computer ratio in Beijing was 15:1, while in the underdeveloped province of Yunnan it was 186:1—this compared to an approximate 5:1 ratio in the United States (Zhang 2004). In China, access is deemed particularly important to serve the widely dispersed total student population of the western provinces. However, access to computers, while a necessary condition, is not sufficient. How computers are used in science and mathematics instruction is what matters in the education of students.

Mathematics and Science Curricula

In science, all Chinese students in grades 7–9 are expected to take foundational two-year sequences in biology, chemistry, and physics. In grades 10–11, students must take six credits (108 hours) in each of these three subjects; additional science modules (generally two credits or some 40 hours) are optional. As an example, the recently reformed secondary biology curriculum sequence is as follows: in grades 7 and 8, the two-year sequence (3 hours per week in year 7, 2 hours per week in year 8) covers biology as inquiry, basic structures of living things, organisms and their environment, green plants in the biosphere, humans in the biosphere, animals' movement and behavior, reproduction, development and genetics, biodiversity, biotechnology, and healthy daily life. An alternative is a three-year (grades 7–9) integrated sequence covering the same topics. The required three high school (grades 10–12) core modules cover homeostasis and the environment, heredity and evolution, and molecular and cell biology. Three optional modules cover modern biological science, biology and society, biotechnology and practice (Liu 2005).

Traditionally, the Chinese high school (grades 10–12) curriculum in mathematics, building on the elementary and lower secondary curriculum, consisted of two distinct, mandatory series, each consisting of several courses: one series in algebra (including elementary calculus and probability) and one series in geometry. This curriculum has recently been reformed to remove some of the most difficult topics and allow for some choice. Five modules, each representing 34–36 teaching hours, are compulsory. They cover sets and elementary functions, elementary solid and plane analytic geometry, elementary statistics and probability, a second module on functions (including trigonometry) and plane vectors, and number sequences and inequalities.

Chinese math and science curriculum sequences contrast sharply with U.S. high schools where students can opt out of more advanced courses.

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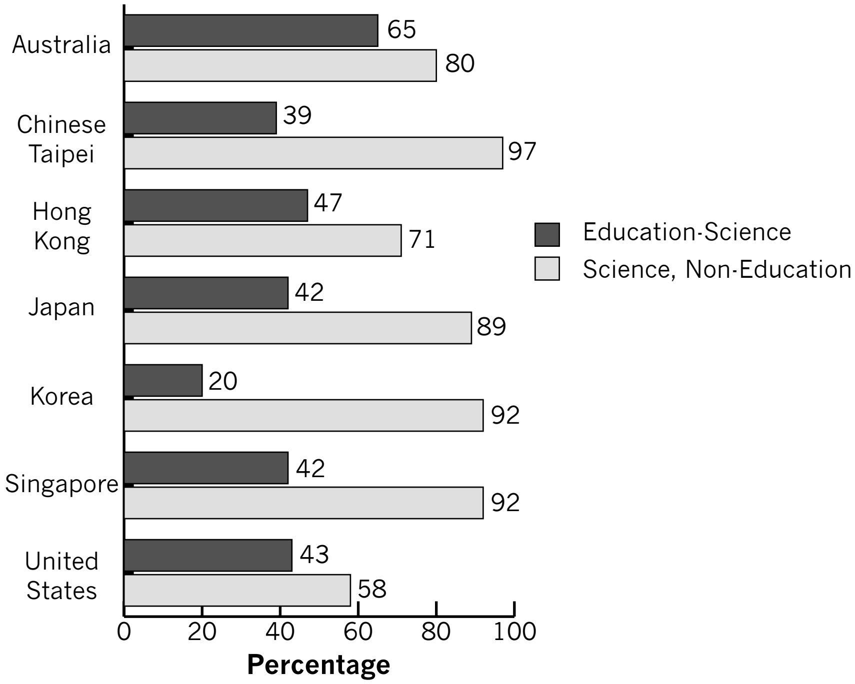
In 2000, nearly 40 percent of U.S. high school students had not taken any course work in science more challenging than general biology.

Both the Chinese science and the mathematics curriculum sequences contrast sharply with the layer-cake approach of U.S. secondary education that allows students to choose among different levels of courses, and ultimately opt out of more advanced learning. Since the 1980s, states have increased the number of mathematics and science courses required for a high school diploma, and this trend inevitably has led to increases in student course-taking in these fields. Nevertheless, in 2000, nearly 40 percent of U.S. high school students had not taken any course work in science more challenging than general biology, and only 18 percent had taken advanced biology, chemistry, or physics. In mathematics, some 55 percent of students had not taken any courses beyond two years of algebra and one year of geometry, and only 18 percent had taken advanced-level courses such as pre-calculus or an introduction to analysis (National Center for Education Statistics 2004).

Preparation of Science and Mathematics Teachers

As Figure 3 shows, the preparation of science teachers in East Asia is considerably more rigorous with respect to their science knowledge than the preparation of science teachers is in the United States. With the exception of Hong Kong, about 90 percent of eighth-grade teachers in these countries (approaching 100 percent in Chinese Taipei) have majors in a field of science, in addition to their science education preparation. This kind of preparation also characterizes Chinese science teachers and

Figure 3: TIMSS 2003, Percentage of 8th Grade Science Teachers with Education-Science or Science Major (Biology, Physics, Chemistry, or Earth Science)



Source: Ginsburg et al. 2005

contrasts with the United States, where fewer than 60 percent of the eighth-grade science teachers have majors in one of the science disciplines. The pattern is similar for mathematics: 80 to 86 percent of eighth-grade mathematics teachers in Chinese Taipei, Japan, and Singapore have math majors compared to 48 percent in the U.S. (Ginsburg et al. 2005). In addition, even at the elementary level, China provides science specialist teachers as early as third grade.

In addition to strong subject matter preparation, prospective teachers in China spend a great deal of time observing the classrooms of experienced teachers, often in schools attached to their universities. Once teachers are employed in a school, there is a system of induction and continuous professional development in which groups of teachers work together with master teachers on lesson plans and improvement. There is also a clear career ladder in teaching, with demanding standards and salary incentives for each step.

Ninety percent of eighth-grade science teachers in East Asia have majors in science compared with 60 percent in the United States.

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China provides science specialist teachers as early as third grade.

Teaching Methods

While there is a great deal of research on what constitutes effective teaching methods for optimal student achievement, neither the United States nor the Chinese education system fully reflects these best practices.

Expertise in mathematics and science entails a firm grasp of concepts and the ability to apply these in new situations (Wieman 2005). Research indicates that instructional methods need to address students' prior knowledge (including misconceptions) and explicitly focus on how to organize and use facts and algorithms in different contexts. There also needs to be ongoing evaluation and suitable feedback to students to guide their developing competence (Wieman 2005).

U.S. national as well as state standards advocate the use of problem-solving in mathematics and hands-on inquiry in science to give students the relevant experiences to understand and apply concepts. For example, in the National Science Education Standards (NRC 1996), the Inquiry Standard is first in a list of grade K–12 curriculum standards for the physical, life, and earth sciences for grades K–12. Students at grade 8 are expected to be able to identify questions that can be answered through scientific inquiry, design and conduct a scientific investigation, use appropriate tools and techniques to gather, analyze, and interpret data, and think critically and logically to relate evidence and explanation. At grade 12, expectations are increased to include recognizing and analyzing alternative explanations. The national mathematics standards call for problem-solving at every grade level for Pre-K–12 (NCTM 2000), defined as building new mathematical knowledge through solving problems that arise in mathematics and in other contexts, applying and adapting a variety of appropriate strategies to solve problems, and monitoring and reflecting on the process of mathematical problem-solving.

The reality of American classrooms, however, may be quite different from these expectations. At the elementary level, observers have noted the frequent use of hands-on activities for their own sake, without drawing out the science concept(s) the unit was designed to teach. A recent study of U.S. middle school classrooms considered lesson design, lesson implementation, mathematics/science content, and classroom culture in its ratings. The observers rated only 15 percent of the 440 classes they observed as exhibiting high-quality instruction, 27 percent were of medium quality, and 59 percent were of low quality (Weiss et al. 2003). As teachers often use the textbook to construct their lessons, the quality of textbooks also deserves attention. In mathematics, U.S. textbooks are full of "problems" that are merely repetitive applications of algorithms, whereas the textbooks of other countries, such as Singapore, "build deep understanding of mathematical concepts through multi-step problems…" that illustrate the application of abstract concepts—much closer to what the U.S. national standards advocate. As further evidence, studies of teaching methods in several countries contrast the extensive use of complex problem-solving by students in Japanese and Hong Kong mathematics classrooms to the rote worksheet problems occupying students in U.S. classrooms (Stigler and Hiebert 1999; Hiebert et al. 2003).

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> Chinese education leaders are concerned about teacher-dominated classrooms and students' lack of independent thinking.

While U.S. leaders are concerned about low standards and quality of instruction in science, Chinese education leaders express great concern about teacher-dominated classrooms and students' lack of independent thinking. This instructional approach is based on deep differences in cultural attitudes between China (and other Asian societies influenced by Confucian philosophy) and Western societies such as the United States. The latter stress individualism and competition, valuing personal achievement and independence. Eastern culture emphasizes the social roles of individuals and classes, valuing collectivism in which individuals work toward the well-being of the whole. This results in a "group-based, teacher-dominated, highly structured pedagogical culture" in classrooms in East Asia (Zhang 2004). Indeed, the Japanese and Hong Kong mathematics classrooms studied by Stigler and Hiebert (1999) are characterized by a considerably greater ratio of teacher-to-student lecturing than in Western countries, particularly the United States.

Testing and Examination Systems

Chinese education is largely examination-driven. In both primary and secondary education, those subjects are emphasized that are required for the national university entrance examinations. Scores attained in the entrance exams for mathematics and for science count highly in differentiating among students seeking college admission. Thus, these subjects receive major attention in the curriculum as well as in student effort.

Such direct linkage between college entrance exams and the K–12 curriculum does not exist in the United States. Although some 20 states currently require high school exit exams for a graduation diploma, and several more are planning to institute such requirements in the next few years, the level of these examinations varies widely, sometimes merely testing minimum competency. There is also often a lack of alignment between state standards and assessments (Porter 2005). Moreover, while mathematics is part of the exam in all 20 states, only 10 require testing in science as well (NCES 2005). As for college entrance examinations in the United States, the most widely used tests assess very little content knowledge in either field. Only if students desire advanced credit or are applying to the most prestigious institutions are they likely to take rigorous examinations in mathematics or in any of the sciences, often through Advanced Placement courses. The American system allows for multiple second chances, such as community college and continuing education, with no single examination cutting students off from further educational opportunities. This is an advantage, but weak math and science preparation in schools may effectively shut out many careers.

Students in China work twice as many hours as their American peers.

Time on Task and Academic Focus

In considering issues of math and science achievement, deeply rooted cultural factors that underlie each system must be kept in mind. Foremost among these is the different roles played by school in the two societies. In China, schools are educational institutions rooted in a continuous cultural history dating back 5,000 years. Chinese students have a strong work ethic, partly due to this deep cultural commitment to education and because pure academic achievement is a lauded pursuit.

By contrast, schools in the United States have adopted a variety of social functions in addition to their educational role: for example, sports, driver's education, and health education. These additional functions lead to varied allocations of school time and resources during the course of a school year, and different schools even in the same jurisdiction make different choices in this regard. Some schools serving populations striving to enter prestigious colleges emphasize academic achievement; other schools concentrate on fielding outstanding sports teams, and so on. However, even across this variety, cultural attitudes toward education lead to a diffuse valuation of academic achievement and significant amount of wasted class time in U.S. schools.

Time on task is far greater in Chinese classrooms, where education is highly valued by students and society in general. And the school year in China at the high school level is a full month longer than the American school year: 200 teaching days as compared to 180.

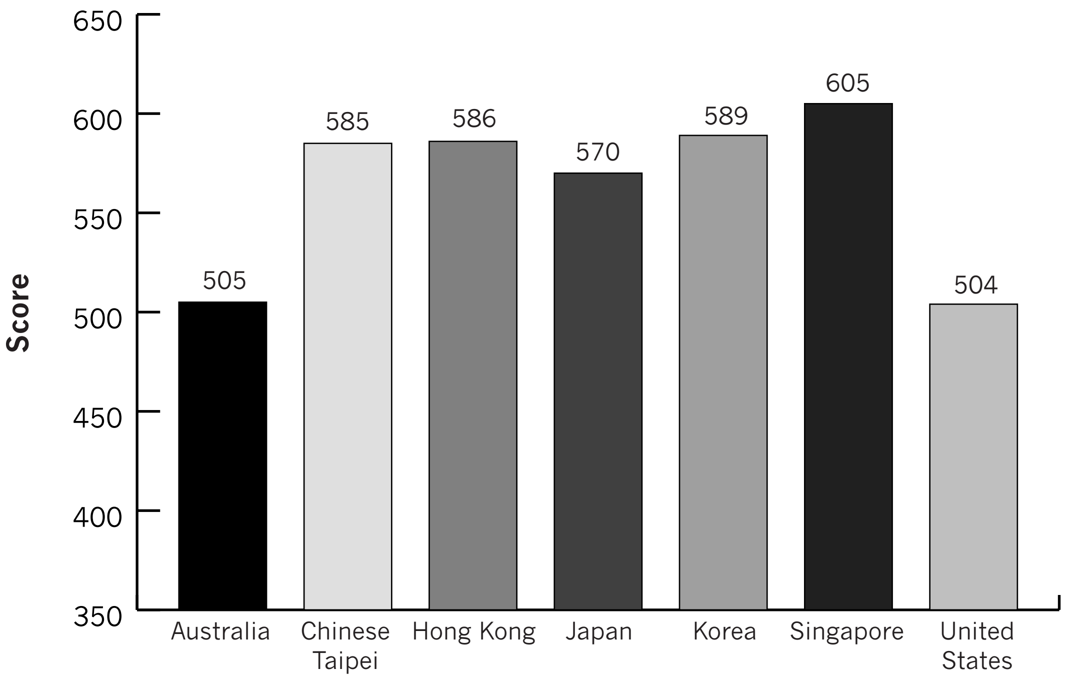
In both countries there are opportunities for out-of-school learning, though academically a great deal is expected of Chinese students. While the convention of studying at home to follow up on school work is common to both countries, the level of intensity and study hours is generally greater in China, particularly as students prepare for high-stakes exams. Students in China work twice as many hours as their American peers. Effort—not ability—is presumed to determine success in school (Stewart 2006). Students whose families can afford the tuition arrange additional instruction, either by an individual tutor or by attending tutoring schools—a common practice in East Asian countries. Furthermore, many students in China attend residential or boarding schools, which also extends their hours of study. One advantage in the United States is that there are many more opportunities for informal science learning through television programs, special science magazines for children, science museums and nature centers, projects carried out within special associations such as Boy Scouts and Girl Scouts groups, and others.

Student Achievement

All of these factors contribute to differences in student achievement between East Asian education systems and the United States. Two such comparisons for student achievement in eighth grade are summarized in Figures 4 and 5. Figure 4 displays the average scale scores for mathematics attained in the 2003 TIMSS test in APEC (Asia-Pacific Economic Cooperation) countries; Figure 5 displays the percentage of eighth-grade students in each of these countries attaining an advanced-level score. The pattern for science achievement in eighth grade is quite similar, with the differences in attainment of the advanced-level score being equally stark.

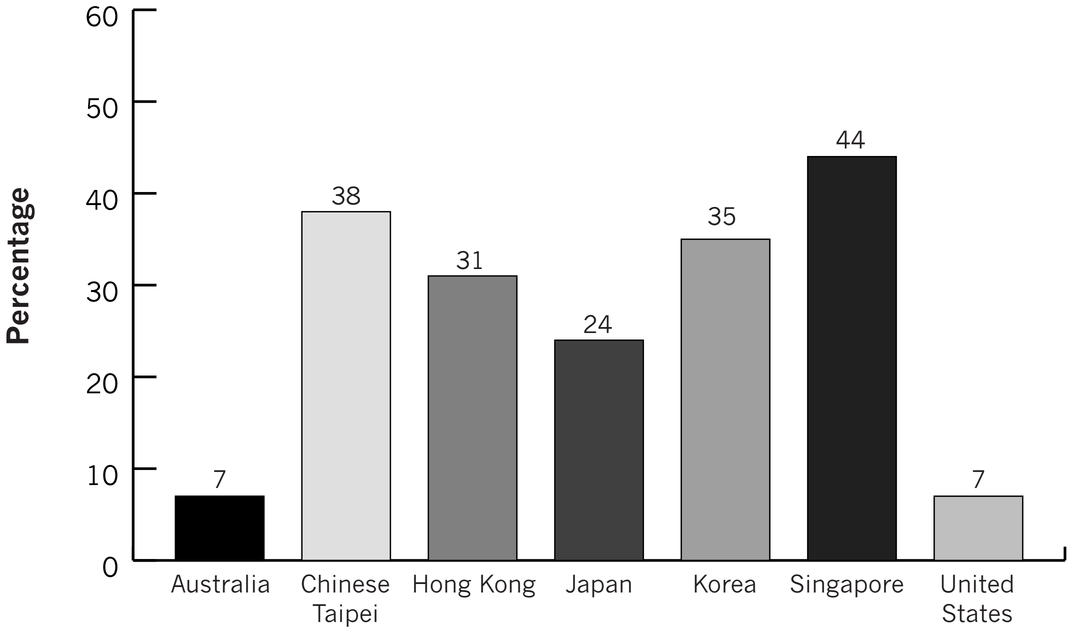
Interestingly, student attitudes show little relation to student achievement in either science or mathematics. As Figure 6 shows, a large percentage of eighth-grade students in the United States exhibit a high level of confidence in their ability to learn science, yet only 11 percent achieved an advanced score in TIMSS 2003. In contrast, the level of confidence of students in Chinese Taipei is half that exhibited by U.S. students, yet 26 percent attained the advanced score. On the other hand, a considerable percentage of Singapore students exhibit high self-confidence; these students are also the highest-performing

Figure 4: TIMSS 2003, Average Math Scores 8th Grade



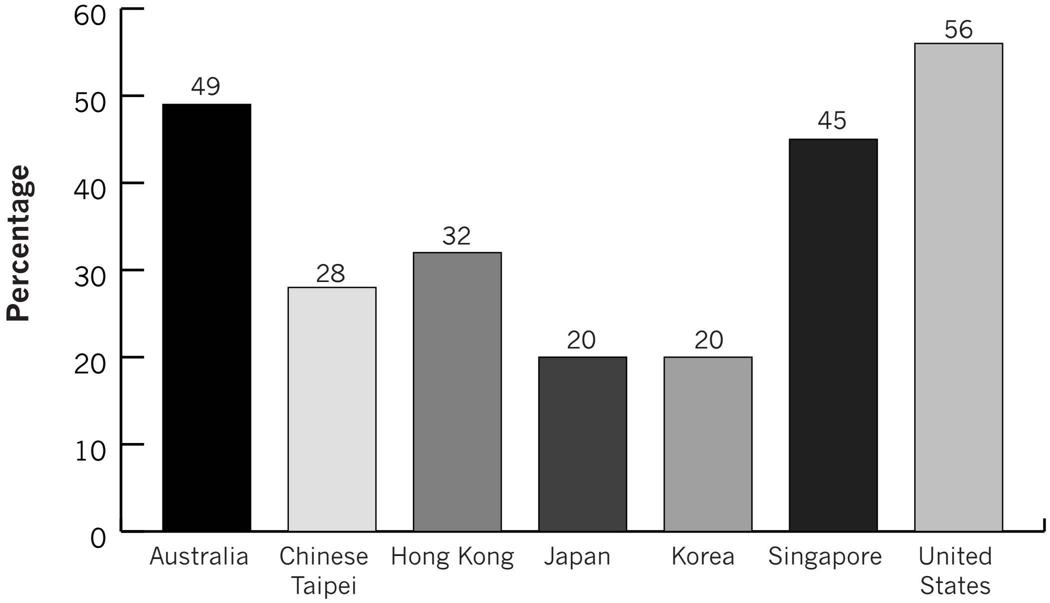
Source: Ginsburg et al. 2005

Figure 5: TIMSS 2003, Percentage Achieving Advanced Math Score (625) 8th Grade



Source: Ginsburg et al. 2005

Figure 6: TIMSS 2003, Percentage of 8th Grade Science Students with High Student Self-Confidence (SSC) in Learning Science



Source: Ginsburg et al. 2005

(33 percent attained the advanced score) among the participating APEC countries. The pattern in mathematics is quite similar.

ISSUES OF COMMON INTEREST

In many respects, the two systems are mirror images of each other: China has a nationally driven system with strong national curriculum standards and regulation of textbooks, a coherent, knowledge-focused curriculum that emphasizes mastery of basic concepts, clear alignment between curriculum and instruction, and strong student work ethic.

The United States, by contrast, is a decentralized system where states and localities make many of the decisions. In the United States there is flexibility, innovation, and more choices, opportunities, and second chances for students throughout their life span so that any assessment of math and science performance should encompass K–16. There is also more use of inquiry and laboratory methods and a greater emphasis on biological and earth sciences than in China. However, major weaknesses include a broad, diffuse, and voluntary set of curriculum standards, with a good deal of redundancy in the "spiral" curriculum design and lack of aligned instruction and accountability, and lack of challenge for many students.

Despite these differences, there are many common areas of interest where educators from each system could learn from the other. These include:

- **degrees of flexibility**
- **curriculum content and instructional methods**
- **examination and assessment practices**
- **teacher preparation and professional development**
- **use of information and communication technology**

Degrees of Flexibility

The two systems of education are almost mirror images of each other, one being characterized by standardization and the other by a great deal of flexibility. Each, however, is moving somewhat toward the middle. China's curriculum is centralized with coherent and consistent standards. Traditionally, this has led to a strong basic education for many students, but little choice. As noted, current reforms have encouraged the development of more than one textbook version and the introduction of some choice of course modules in the upper secondary system.

In the United States, because education is the responsibility of individual states rather than the federal government, learning standards and curricula vary widely, even though voluntary national standards exist. Moreover, students have a wide array of choices among curricular offerings. While there are loose checks on these choices (e.g., state requirements for obtaining a high school diploma, entrance requirements and test scores set by the more prestigious colleges and universities), it is quite possible for a U.S. student to graduate from high school without any credits in either physics or chemistry.

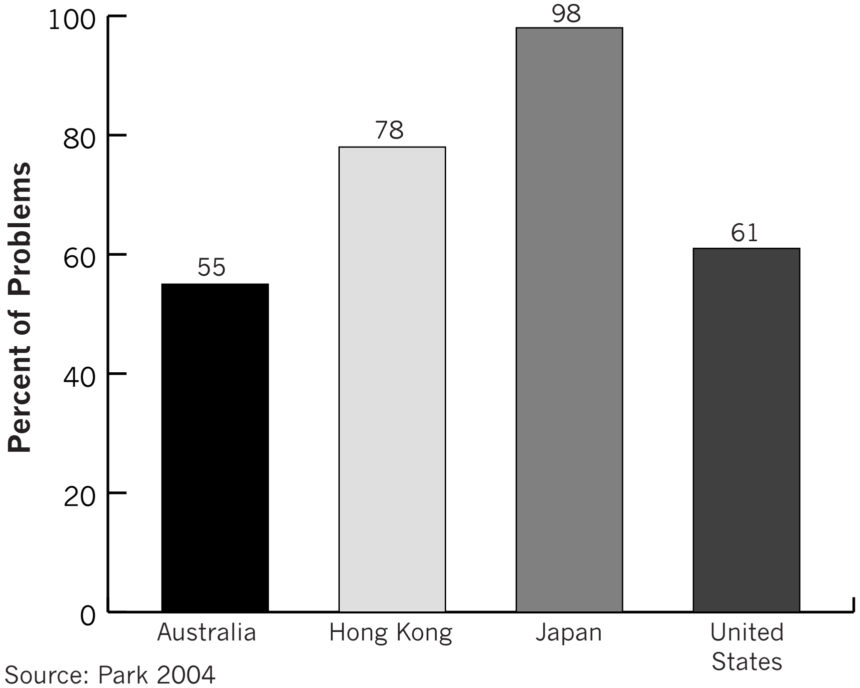
However, even when students' choices lead to a poor preparation for tertiary education, students in the United States have numerous "second chances," such as redundant curricula, attending community colleges that have few entrance requirement, remedial courses in college, or alternative training opportunities including distance learning through online courses. In the twenty-first century, what is the best balance between a rigorous standardized core curriculum, and choice and innovation?

Curriculum Content and Instructional Methods

As U.S. states are moving toward more rigorous curricula, there is great interest in the K–12 mathematics and science standards of countries whose students perform well in international assessments. There also is concern with the "word-rich and math-poor" U.S. textbooks and their low level as contrasted with the more structured and coherent textbooks and curriculum materials used in well-performing countries. For example, the Singapore mathematics materials are two grade levels more advanced than U.S. texts. The situation is similar for science, as exemplified by the contrast in U.S. and Japanese text materials intended for students in the elementary grades (Ginsburg et al 2005). The Video Study of eighth-grade mathematics lessons in five countries associated with the 1999 TIMSS assessment demonstrated the repetitiveness of the mathematics curriculum in the United States. In the 50 to 100 lessons observed in each country over the course of a school year, old material taught in a previous lesson was reviewed 53 percent of the time as contrasted to only 24 percent of the time in Hong Kong and Japan (Park 2004). Moreover, as Figure 7 indicates, more complex problems requiring lengthier student work were encountered more frequently in the classrooms of these two countries than in the United States.

Singapore math materials are two grade levels above U.S. texts.

Figure 7: TIMSS 1999 Video Study, Average Percentage of Problems per Lesson Worked on Longer Than 45 Seconds



Source: Park 2004

Another area of interest to American educators is the sequencing of courses that lead to more advanced learning on the part of East Asian students. Through the lower and upper secondary grades, these students are exposed to rigorous mathematics courses as well as to several years of courses in each science. In both cases, the courses deal with more advanced content than in the United States. While American science and mathematics curricula at the secondary level offer a variety of choices, in many schools they lack a strong core.

China, on the other hand, is interested in adding some choices to the existing strong core. As the recent curriculum revisions noted above indicate, course sequences for biology, chemistry, and physics continue to be mandatory at the lower secondary level. At the upper secondary level, a certain number of modules in each discipline are required as well, but the curriculum provides opportunities for choices of additional science modules beyond the requirements.

Reformers in China also want to introduce a greater variety of instructional methods. Chinese students striving for university entrance are highly competent in their knowledge of factual information and ability to perform complex algorithmic operations. However, Chinese researchers and ministry officials have criticized the current system for failing to encourage creativity and the ability to carry out scientific inquiry. In their instruction, teachers need to give more consideration to individual students, encourage students in their own active learning, foster their hands-on skills by involving students in project work, and "teach them to fish instead of giving them the fish" (Wang 2005)—that is, teach students how to learn on their own and become lifelong learners.

Examination and Assessment Practices

At the national level in China, there are two types of examinations: graduation exams from high school and the all-important (and more difficult) college entrance examinations. At the secondary level, Chinese textbooks are oriented toward the national examinations. The college entrance examinations are governed by university professors and designed to select students for entry into top universities. Therefore, students try to follow the national standards as closely as possible in order to get high marks on the examinations. Students are drilled for quick responses based on memorization of a great deal of material. China is in the process of reforming the college entrance examinations while trying to preserve their emphasis on content knowledge and rigor. However, there is much resistance to this reform by both teachers and university professors who view any attempt at revision as a "watering down" of standards. In addition to reforming the college entrance examination, China is trying to decentralize its examination system in general. Thus, as of 2004, about one-third of the 31 regions have authority for instituting their own examination systems, based on the new science and mathematics curriculum being introduced, with more emphasis on critical and analytical thinking.

China is in the process of reforming the college entrance examinations while trying to preserve their emphasis on content knowledge and rigor.

Traditionally, in the United States, a great variety of tests have been administered. Some are created and determined by the classroom teacher, others by the local school authority, still others by the state. The latter have been increasing in frequency, due to the No Child Left Behind (NCLB) Act. In contrast to China, which has no national examination system at the elementary or middle school level, this law emphasizes testing in the lower grades, though states decide on which tests to use and what benchmarks to set. In order to spur reform—particularly to reduce "the achievement gap" between certain minority groups and white students—the NCLB Act prescribes consequences for schools and administrators if they fail to meet annual milestones for improving student performance. The only direct consequence of any test for students is to have to repeat a grade if they do poorly on a number of measures. Also, students who aspire to enter one of the prestigious colleges or universities need to perform well on a variety of college entrance exams, such as the SAT, ACT, and/or AP course exams.

Teacher Preparation and Professional Development

Both countries have needs in continuing professional development for teachers of science and mathematics, though the specifics vary. For example, as discussed above, many U.S. teachers, particularly at the elementary and lower secondary levels, lack adequate preparation in the subject matter content they are expected to teach. While there are several effective methods for remedying these deficiencies (see, for example, Loucks-Horsley et al., 2003), the problem for the United States is one of scaling up, that is, reaching the thousands of teachers with intensive enough professional development methods to bring their science and/or mathematics knowledge to the required level of competence so that they can become effective in the classroom.

For China, whose teachers are well prepared in subject matter content, at least in the major metropolitan areas, the need is for changing teachers' instructional methods to match the curricular reforms being instituted, with greater stress on involving students in active participation through questioning and giving them scope for critical thinking and development of creativity. This is not an easy task, as teachers are ingrained in their traditional methods. Hence, they do not have the teaching skills to work with students using some of the reform pedagogic strategies or to design lessons that incorporate them effectively. Moreover, teachers are concerned that their students will not do well in the examinations if they deviate from traditional teaching methods. In training the many rural teachers as part of the effort to institute universal education through grade nine, Chinese education authorities realized that reforms are needed in teacher preparation. They have found it useful to analyze teacher training methods in use in other countries.

Use of Information and Communication Technology

In the wake of a technological revolution around the world, schools in both China and the United States are exploring the application of new information and communication technologies to extend opportunities for learning to underserved groups and to provide effective instruction for their teachers. While a great deal is being invested in infrastructure—wiring schools and improving access to computers—research now shows that this hardware investment is typically not accompanied by effective classroom application. Student-to-computer ratios generally are poor indicators of how technology in the classroom is impacting student learning. There is no concrete evidence that links technology in the classroom to improved test scores. With minimal technology training, most teachers continue to teach the same curriculum in the same manner (Zhao 2005).

> To achieve the widespread integration of information and communication technology in education, schools need to adopt a holistic strategy that addresses not only technological and pedagogical issues, but also the transformation of school cultures.

However, the potential is great. Most current uses of technology do not take advantage of the capacities of the medium. For both countries, there is potential in integrating technology into the science and mathematics curriculum in three areas:

- Technology as a teaching tool;
- Technology as a student learning tool; and
- Technology as a base for new teaching and learning models.

For instance:

1. Virtual or e-learning for students can provide access to courses and subject matter expertise where local resources are scarce. This is particularly salient in addressing the needs of underserved groups: rural populations in western China or minority and rural groups in the United States.
2. Similarly, teachers can gain access to professional development via virtual or e-learning opportunities.
3. Simulation and gaming offer another important opportunity for learning. Through simulations, educators can more directly represent an expert's model of a physical phenomenon, demonstrate what cannot be seen in real time (i.e., speed up or slow

down phenomena), and de-emphasize the unnecessary errors that occur in hands-on experiments.

4. Technology also provides a platform for collaboration, either teacher-student and student-student communication, and makes data recording and analysis more efficient.
5. Through international school-to-school joint projects, students can improve their technological literacy while also learning critical global competencies (Roberts 2004). Finally, there are many inexpensive ways of using technology in the classroom that make learning mobile and dynamic.

While technology offers a range of opportunities to improve mathematics and science education in both countries, there are also significant challenges that go beyond building adequate infrastructure (both hardware and software). These include:

- Evaluation of the effectiveness of technology for student learning;
- Reforming examination and assessment systems so that they reflect student learning through technology, rather than inhibit it (this also includes using technology more effectively for assessment itself);
- Ensuring that students are not distracted from their learning by games and other non-instructional uses of technology; and
- Providing professional development to teachers to allow them to take advantage of technology-based curriculum content and instructional strategies.

Thus the overall challenge is to move beyond a focus on access to information technology to actual integration of technology-based curricula.

POSSIBLE AREAS OF COLLABORATION

Given the contrasting challenges and often complementary strengths of both education systems, the U.S. and Chinese Forum participants saw greater collaboration and sharing of resources as mutually beneficial. They agreed on a set of principles to guide the most promising collaborative projects. They also prioritized areas of interest to both countries that may warrant collaborative research, development projects, educational partnerships, and exchange projects.

Guiding Principles

The following considerations should guide the selection of future collaborative efforts:

1. The activity under consideration should address an issue of significant importance to both countries.
2. Each project or collaborative effort should have a well-defined set of expected outcomes, achievable in incremental steps.
3. Timelines should be established that relate to the defined outcomes.
4. Partnerships should be clearly defined, e.g., government-to-government, university-to-university, state-to-province, city-to-city. At present, requisite mechanisms are missing to develop and maintain some of these partnerships on a systematic basis.
5. Methods of support and, specifically, who will fund what part of any proposed activity, should be established ahead of time, and the necessary funding clearly committed.

Potential Areas of Collaborative Work

The Forum participants identified a variety of areas of common interest that could be fruitfully addressed through collaborative efforts. A number of the areas of potential collaboration identified by participants are interrelated. Nevertheless, they are discussed separately below, with connections indicated, so as to encourage development of well-defined projects in accord with the Guiding Principles.

1. Comparative Study of Curriculum Standards and Examination Systems

National and provincial/state student testing and examination systems have great influence on and, in some cases, determine what science and mathematics students study and what competencies they are expected to acquire. Therefore, understanding the advantages and disadvantages of assessment systems, together with tracking and evaluating the efforts in each country to reform its national and state systems, was assigned a high priority by participants. An important element in such studies will be comparisons of the curricular standards on which the examinations are based, as well as analyses of the textbooks of the two countries to better understand what kind of learning is valued and therefore embedded in the examinations and assessment systems of each. An important issue is the extent to which curricular standards, textbooks, and examinations are well focused (as in most East Asian countries) or lack focus (as in the United States), and how well these determinants of what students are expected to learn are aligned with each other.

2. Comparative Study of Classroom Testing Practices

Of interest to both countries is the extent to which classroom testing practices are consonant with the national (state/provincial) goals; what role the tests play in assigning grades to students, how they determine what teachers emphasize in their instruction, and what students concentrate on in their study. Studies show that U.S. teachers generally are unskilled at developing good tests and often either use the test questions or problems suggested at the end of a textbook chapter, or fashion simple multiple-choice quizzes. Chinese teachers, as well, use “a hundred marks” to grade students instead of more holistic assessments that encourage students in all aspects of their learning rather than just rote memorization (Wang, D., 2005).

3. Implementation of Best Practices in Professional Development

Both countries have enormous need for training teachers already in the classroom, although these needs are quite different. For China, there are two distinct types of needs: One is getting experienced teachers in lower and upper secondary schools to expand their repertoire of instructional strategies so that the current reform in the science and mathematics curricula will be successfully carried out in the classroom. A second is to train teachers in the more rural western provinces so that they possess adequate science and mathematics knowledge and can use effective instructional strategies to carry out the mandate for universal education.

For the United States, the primary need is “going to scale,” that is, implementing what is known to be effective with small groups of teachers to reach the thousands of teachers in both elementary and secondary schools who are in need of a stronger foundation in math and science. A key issue is how to reach weaker teachers—those who are least likely to volunteer for professional development and most likely to need it. A second important need is to equip teachers to provide effective instruction for students from minority groups and children in poverty who now lag behind in science and mathematics achievement.

4. Teacher Preparation

In addition to the great in-service needs in this area, there is need to reform the pre-service preparation of prospective science and mathematics teachers in both countries. True student understanding at all levels, K–16, involves a firm grasp of facts and concepts and the ability to apply these in new situations. To teach for this kind of understanding, teachers need both content mastery—facts and structure—and pedagogical knowledge—how students learn mathematics and science and how to deal with the special learning challenges posed by various topics and at various levels (Wieman 2005). U.S. students arrive at college with much weaker foundations in math and science than their Chinese counterparts. Thus the content preparation of prospective U.S. teachers must spend a great deal more time developing basic conceptual understanding than would be necessary in China. In both countries, there are difficult institutional barriers that inhibit reforming the current undergraduate science and mathematics courses for prospective teachers. In particular, introductory courses focus mainly on facts and very little on organization and uses of facts. Most pre-service teachers learn science and mathematics content through memorization and this is the teaching style they then carry into their own classrooms, particularly since it was successful for them in passing exams and is likely to be so for their students. There would be great benefit in mutual exchanges to sites that provide exemplary teacher education, e.g., Chinese teacher training universities that prepare teachers with deep subject matter knowledge, and U.S. institutions that prepare teachers to engage their students in authentic science inquiry and mathematical problem-solving.

CHENGO, an online game-based program for beginning Chinese in the United States and beginning English in China, is being developed jointly by the U.S. Department of Education and the Ministry of Education of the People's Republic of China.

5. Information and Communication Technology

There is much scope for collaborative development of interactive software to teach science. As was demonstrated in one of the Forum sessions, excellent models exist, such as CHENGO, the program for teaching Chinese developed collaboratively by the U.S.-China E-Language Learning System, a joint project of the U.S. Department of Education and the Chinese Ministry of Education, and the physics modules developed by Professor Wieman. For the United States, such interactive models might ease the burden of having unqualified teachers teaching science, either by increasing their competence through distance learning or through reaching the students directly. Similarly, such courseware could help in China's initiative to implement a ninth-grade education throughout the rural areas of the western provinces. Participants stipulated a number of conditions for successfully carrying out such collaborative development projects. On the U.S. side, it would be advantageous to engage the nonprofit sector, perhaps the National Science Teacher Association, in such a venture. Technical workgroups should bring together scientists, science educators, instructional design experts, and software engineers. These groups might undertake extended technical reciprocal visitations, as well as use videoconferences, intensive workshops, and face-to-face sessions to help refine prototypes for effective use in both countries. Thorough evaluation of prototypes must be undertaken to guide continuous modification and improvement.

Linked to the development and use of information and communication technology in instruction is a better understanding of how students learn in such environments. In the United States, much of the current generation of students is immersed in this technology, spending many more hours per week with some form of it than in school. This is also becoming true of some students in China's metropolitan centers. Research is needed as to the most effective formats and designs for instructional modules on science and mathematics topics intended for students at different levels. For example, might some modules be couched in the form of interactive computer games? How can modules be internationalized yet be adaptable to suit different locales and levels of technology use?

6. Serving Rural and Minority Students

As noted earlier, both countries have sizable student populations that are not benefiting sufficiently from the current system of mathematics and science education. In the case of China, these are students dispersed over wide geographic, mostly rural, areas. This condition exists in the United States as well, though not to the same extent. In the United States, students living in poverty and/or belonging to certain minority groups (African-Americans, Hispanics) do not profit by the science and mathematics education proffered them. Professional development and teacher preparation must be designed to help teachers be more effective instructors for these students. Courses developed for delivery through information and communication technology may also address, at least in part, the need for serving rural and minority students and their teachers.

7. Serving Gifted Students

Some concern was expressed that, at least in the United States, the stress on closing the "learning gap" that persists for minority students may lead to neglecting the nurture of the students most gifted and talented in science and mathematics. Because of budget strictures and mandated expenditures in other areas, programs for such students have been eliminated in many schools. Especially with today's concerns about ensuring an adequate supply of professionals in science, mathematics, engineering, and technology—including teachers at the K–16 levels—the United States may have much to learn from studying Chinese residential and key high schools as to how to encourage and provide appropriate learning opportunities for gifted and talented students.

8. Elementary School Science

What science is it important for elementary school teachers to know? Since China provides specialist science teachers in upper elementary school, this becomes in part a question as to how much formal science should be taught in the lower elementary grades in that country. In that regard, it is instructive to note that some of the highest-scoring countries in TIMSS (Japan, Singapore) do not introduce formal science until upper elementary school. American standards, however, recommend the teaching of science at the earliest grades, yet the use of science specialist teachers in elementary school has virtually disappeared from most school systems. Should specialist science teachers be introduced into American elementary schools? When generalist teachers are responsible for instructing all subjects through Grade 5 or even beyond, then what science courses should be required in their pre-service education? What should be the content of these courses so that prospective teachers will be competent to handle the science to be taught in elementary school? What professional development should be designed and made available to them, once they are in the schools, to maintain or even increase their science teaching competence?

9. Advanced (Graduate) Education for Teachers and Other Education Professionals

One of the ways in which both systems can scale up effective teaching strategies is to reevaluate pre-service teacher education and advanced education for other education professionals. More collaborative research is needed on graduate education for specialist teachers and teacher leaders, education administrators, teacher training faculty, researchers, and other professionals in mathematics and science education. For example, the U.S. National Science Foundation is supporting several Centers for Learning and Teaching that in part are addressing what constitutes appropriate graduate education in these fields. One of these Centers has developed two course sequences for graduate students planning to enter careers focusing on school mathematics: One is a series of alternative advanced mathematics courses that deal with K–12 mathematics in great depth rather than offering graduate students only the traditional advanced courses that have nothing to do with the mathematics taught in school; the second is a sequence of mathematics methods courses that deal with issues in mathematics education and instructional strategies effective for teaching various topics at the elementary and secondary levels. In addition, these graduate students are involved in research and development directly related to K–12 mathematics and the preparation of school teachers.

10. Leadership for Reform in Science Education

Participants agreed that, to ensure successful science and mathematics education in the schools, principals, provincial and state education authorities, university faculty, and national education leaders in both countries need to understand and support current reform efforts and the rationale behind them. Therefore, approaches to professional development for these administrators and leaders must be designed to suit their roles and responsibilities so that they can and will support classroom teachers charged with implementing each country's reform efforts. While any given activity may have to be designed to suit each country's specific conditions, there may be enough similarities in roles and responsibilities to make some collaborative exploratory work worthwhile.

Methods of Collaboration

The Forum participants made recommendations about specific methods of exchange and mechanisms of collaboration. For example:

1. Some areas of interest lend themselves to joint comparative research; these include comparisons of curriculum standards, textbooks, and assessment systems, models for teacher preparation and professional development, and programs for gifted and talented students.
2. For some of these same areas, mutual observation of practices in each country through "shadowing" of principals and teachers to observe curriculum and instruction might be of great value, including observations of pre-service education of teachers. A supplement to "shadowing" is the use of videotapes of science and mathematics classrooms, as well-established methods of analysis of such tapes are readily available.
3. Work addressing a third set of areas, particularly the use of information technology for science and mathematics instruction, will need to rely heavily on long-term development efforts, modeled on the expertise acquired in developing CHENGO and other successful interactive technology programs.

A variety of education partnerships will be necessary to carry out these different types of work. For example, partnership agreements between American states and Chinese provinces with linkages to schools and teacher preparation institutions could further teacher and principal "shadowing" projects, as well as joint science projects by students working together through the Internet. The Chinese government has expressed a willingness to offer scholarships for scholars and teachers interested in participating in "shadowing" projects. On China's side, the development of information technology projects could be funded through the new rural distance education initiative, whereas funding would have to be sought on the U.S. side from various sources, such as the National Science Foundation, private nonprofit foundations, and possibly the for-profit commercial sector (considering the potentially vast audience of more than 100 million Chinese students).

The Ministry of Education of the People's Republic of China would likely take the lead for appropriate follow-up activities for China. On the part of the United States, responsibility is not that clearly delineated. Some activities might fall in the bailiwick of the U.S. Department of Education, as specified in a renewed Memorandum of Understanding between the Ministry of Education and the U.S. Department of Education. Others might be supported through the National Science Foundation and the National Institutes of Health; still others through private corporations and foundations. Nonprofit and professional organizations as well as universities would manage such projects. Consideration should be given to establishing a bi-national Advisory Committee to oversee the various projects as they are initiated, to monitor progress toward their intermediate and long-term outcomes, to keep them in communication with each other, and to ensure their ties to national, state/provincial, and local needs.

CONCLUSION

As globalization becomes an increasingly prominent feature of our time, the international exchange of ideas fuels new thinking. Educational innovations are taking hold around the world. Educational ideas from one setting may not be totally applicable in other settings. Yet they can yield useful adaptations as nations strive to prepare their children for a world in which shared science and technology, and increased communications across boundaries of language and cultures become the norm. The United States can no more afford to isolate itself educationally than it can economically or in terms of national security. Currently most educators know little about education in other countries. As countries around the world are instituting fundamental reforms, we need a globally oriented world-standard education to prepare our young people for leadership. While the United States has much to learn from other countries, it simultaneously has an important role to play in improving education around the world—a role that is an increasingly important part of its international engagement.

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APPENDIX A: List of Participants

U.S. Delegates

Rodger BYBEE, Executive Director, Biological Sciences Curriculum Study (BSCS)

Janice EARLE, Senior Program Director, National Science Foundation

Bruce FUCHS, Director, Office of Science Education, National Institutes of Health

Alan GINSBURG, Office of the Under Secretary, Planning and Evaluation Service, U.S. Department of Education

Joanna LU, Managing Director, Seeing Math Telecommunications Project, Concord Consortium

Andrew PORTER, Rodes Hart Professor of Educational Leadership and Policy and Director, Learning Sciences Institute, Vanderbilt University, Department of Leadership, Policy and Organizations

Senta RAIZEN, Director, National Center for Improving Science Education/WestEd

Piedad ROBERTSON, President, Education Commission of the States

Richard SCHAAR, Executive Advisor on Math and Science Education, Texas Instruments, The Business Roundtable

Susan SCLAFANI, Assistant Secretary, Office of Vocational and Adult Education (OVAE), U.S. Department of Education

Vivien STEWART, Vice President, Education, Asia Society

Uri TREISMAN, Professor of Mathematics and Director, The Charles A. Dana Center, The University of Texas at Austin

Marc TUCKER, President, National Center on Education and the Economy

Juefei WANG, Director, Asian Studies Outreach Program, Assistant Professor of Education, The University of Vermont

Gerald WHEELER, Executive Director, National Science Teachers Association

Carl WIEMAN, Chair of the Board on Science Education, The National Academies

Distinguished Professor of Physics, University of Colorado at Boulder

Hung-Hsi WU, Professor of Mathematics, University of California, Berkeley

Lea YBARRA, Executive Director, Center for Talented Youth, Johns Hopkins University

Yong ZHAO, Professor and Director for the Center of Teaching & Technology, Michigan State University

Chinese Delegates

CHEN Xiaoya, Vice Minister, Ministry of Education

YANG Jin, Deputy Director General for Basic Education, Ministry of Education

CENG Jianjun, Deputy Director-General for International Cooperation and Exchange, Ministry of Education

CHEN Li, Deputy Dean of School of Educational Technology & Director of Research Center of Distance Education, Beijing Normal University

GAO Song, Professsor of Chemistry, Beijing University

JING Wei, Deputy Director, Division of America and South Pacific, Ministry of Education

LIAO Boqin, Professor of Physics, Southwest Normal University

LIU Enshan, Dean for Biology, Beijing Normal University

MI Qi, Physics Teacher, High School Affiliated with Chinese People's University

SHEN Yushun, Director, National Training Center for Secondary School Principals, Ministry of Education

TANG Shengchang, Master Principal/Master Teacher, Shanghai High School

WANG Dinghua, Director, Department of Basic Education, Ministry of Education

WANG Jianpan, President, East China Normal University

WEI Liqing, Director, Special Projects, Department of International Cooperation and Exchanges, Ministry of Education

YANG Hui, Deputy Director General, Fujian Provincial Education

ZHENG Fuzhi, Director General for Inspection, Ministry of Education

ZHOU Haobo, Deputy Director General, Liaoning Provincial Education

ZHOU Wei, Mm Chen's Secretary, Ministry of Education

Rapporteurs

Marta CASTAING, Program Associate, Asia Society

Weiwei WANG, Intern, Asia Society

APPENDIX B: Agenda

U.S.-China Education Leaders Forum on Math and Science Education

Meeting Chairpersons: Susan Sclafani, Assistant Secretary, Office of Vocational and Adult Education, U.S. Department of Education and Yang Jin, Deputy Director General for Basic Education, Ministry of Education

<u>Monday July 11</u>

8:30–9:30 A.M. Continental Breakfast

9:00–10:30 Opening Session

Welcome: Piedad Robertson, President, Education Commission of the States

Introduction: Vivien Stewart, Vice President, Education, Asia Society

Keynote address: Chen Xiaoya, Vice Minister, Ministry of Education of the People's Republic of China

Introductions by participants

Keynote addresses will discuss: What are the key concepts and what level of math and science do secondary school graduates need today? How well is the United States or China doing in teaching this to some students/all students? What are the key barriers to reaching these goals and what are some of the most promising innovations that might overcome these?

10:30–11:00 Break

11:00–12:30 P.M. Science Standards, Curriculum and Assessments

Two speakers will make brief opening remarks to start the discussion: Gao Song, Professsor of Chemistry, Beijing University, and Alan Ginsburg, Office of the Under Secretary, Planning and Evaluation Service, U.S. Department of Education

Guiding questions: What are the strengths and weaknesses in current science standards, curriculum design, and assessments in China and the United States?

12:30–1:30 Lunch

1:30–3:00 Math Standards, Curriculum and Assessments

Two speakers will make brief opening remarks to start the discussion: Andrew Porter, Rodes Hart Professor of Educational Leadership and Policy and Director, Learning Sciences Institute, Vanderbilt University, Department of Leadership, Policy and Organizations, and Wang Jianpan, President, East China Normal University

Guiding questions: What are the strengths and weaknesses in current math standards, curriculum design and assessments in China and the United States?

3:00–3:30 Break

3:30–5:00 Uses of Technology

Two speakers will make brief opening remarks to start the discussion: Chen Li, Deputy Dean of School of Educational Technology and Director of Research Center of Distance Education, Beijing Normal University, and Yong Zhao, Professor and Director for the Center of Teaching and Technology, Michigan State University

Guiding questions: What are the most promising ways in which media and information technologies can address the problems in curriculum, assessment, teaching and learning environments outlined in the previous sessions?

6:30 Dinner at McCormick's in the Historic Oxford Hotel

Tuesday, July 12

8:30–9:30 A.M. Continental Breakfast

9:00–10:30 A.M. Teaching and Learning

Two speakers will make brief opening remarks to start the discussion: Wang Dinghua, Director, Department of Basic Education, Ministry of Education, and Carl Wieman, Chair of the Board on Science Education, The National Academies and Distinguished Professor of Physics, University of Colorado at Boulder

Guiding questions: What forms of instruction lead to a firm grasp of central math and science concepts and ability to apply them in new situations? What are the best practices in teacher preparation and professional development that produce this level of understanding? What key improvements are needed in learning environments?

10:30–11:00 Break

11:00–12:30 P.M. Small group discussions

12:30–2:00 Lunch

2:00–3:30 Future Areas of Collaboration

Guiding questions: What are the most promising areas and possible mechanisms for collaboration and joint projects between China and the U.S. with respect to research on math and science education, teacher professional development and exchange, uses of technology, and sharing of best practices

3:30–4:00 Closing Comments