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On the Mathematics Achievement Gap Between the United States and Hong Kong: A Survey-Based Analysis

Sui-Yan Chan
Pablo Zafra

Kean University, U.S.A.

As reported in the Program for International Student Assessment, many Asian countries perform better in Mathematics compared to the United States. In our study, we specifically focused on analyzing the Mathematics achievement gap between the United States and Hong Kong (China). We surveyed middle school and high school teachers from both countries and compared their responses to teaching practices, instructional methods, learning environments and attitude questions. We also discussed a brief comparison of the education systems between the two countries, including the mathematics curriculum and standards. In summarizing the results of the survey, we have provided further insights into the differences between their education systems. In our conclusion, we identified plausible reasons that will help explain the disparity in the Mathematics achievement between the United States and Hong Kong.

Key words: Mathematics education k-12, United States and Hong Kong, PISA, OECD

According to the 2012 Program for International Student Assessment (PISA) report, the United States has performed below average and is ranked 36th in the world education ranking in Mathematics, while the top rankings have been overtaken by many Asian countries including Hong Kong (China). The PISA is an international assessment for 15-year old students to evaluate their abilities in Reading, Mathematics and Science. It was developed by the Organization for Economic Cooperation and Development (OECD), an international organization of 34 countries to help these governments work together to tackle economic issue and world trade. It has been administered every three years since 2000 and the report is closely watched globally by policy-makers and researchers so that they can compare and evaluate their current education policy in relation to different countries (OECD, 2013).

The PISA reports between 2000 and 2012 indicate that the United States students' Mathematics scores has continued to lag behind Hong Kong – the US placing 19th at its highest rank and 36th at its lowest. Hong Kong has consistently placed in the top three (placing 1st at its highest rank and 3rd at its

lowest). Moreover, the average Mathematics scores for the United States students were consistently below those of other OECD students, as shown in Figure 1. (OECD, 2013)

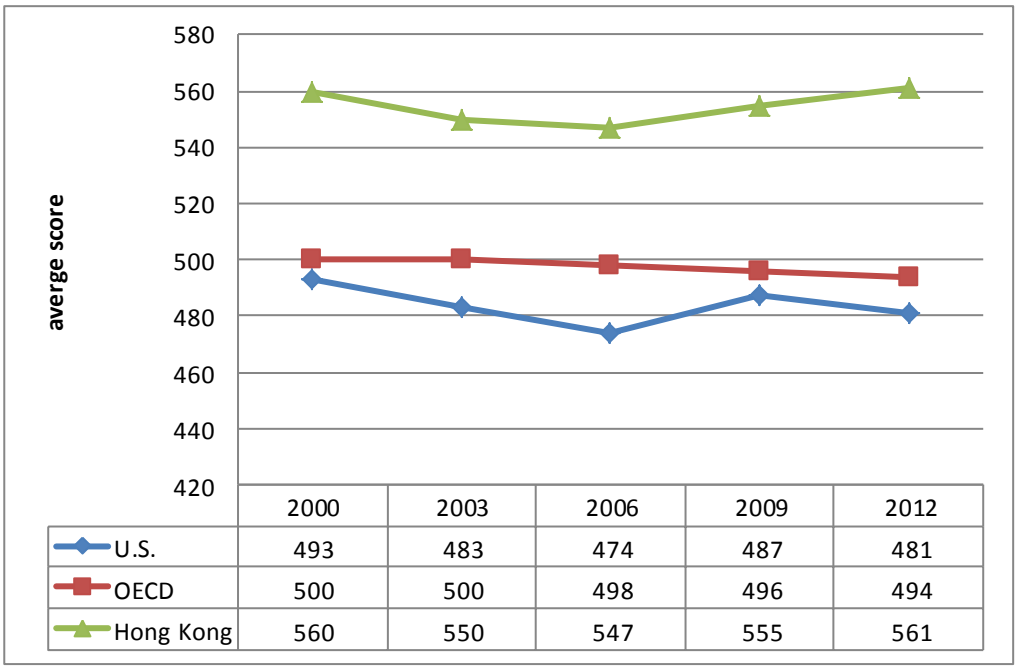

Figure 1. Average scores in mathematics between the United States, OECD and Hong Kong, according to the PISA reports from 2000 to 2012.

These reports showing the superiority of Asian students in Mathematics tests did not seem to surprise the educational community. It has usually been expected that Asians would achieve better performances in Mathematics than Americans. Mr. Nick Diaz, who taught middle school Mathematics for over 30 years in Frederick County Public Schools (FCPS) in Maryland, shared his unforgettable experience when he was coaching the MATHCOUNTS competition team in 2009. One of his students said that their team would not have much of a chance of placing high in the competition because they did not have any Asian students on their team (Diaz, 2010). The general stereotype is that Asians are good at Mathematics because they are smarter, can learn Mathematics much faster, recognize knowledge more deeply, and are much quicker at arriving at answers. However, our research survey indicated that differences in educational systems, teaching practices and learning environments may be greater contributing factors than the general perception of Asians possessing "smart genes" in mathematics.

Brief Comparison of Education Systems between Hong Kong and the United States

First, children in Hong Kong enter the school two years earlier than in the United States (CDC, 2001). Therefore, the introduction of topics into the curriculum in Hong Kong is on average two years earlier than the United States. Second, the table shows that from middle school to tertiary education, the United States adapts "3-4-4" system while Hong Kong has a "3-2-2-3" system.

The education system in Hong Kong can be described as "exam-centered." Hong Kong students not only have at least a mid-term exam and a final exam every school year, but they also have five standardized assessments and examinations from Primary and Secondary school, i.e. Basic Competency Assessments (BCA), Hong Kong Certificate of Examination (HKCEE) and Hong Kong Advanced Level Examination (HKALE). The results of these assessments and exams are used by students in order to decide to enroll to better schools or continue their studies in higher education. Conversely, the United States students have less stress from examinations. Even though they have yearly assessments in 3rd through 8th grades, the main purpose of these assessments is to measure whether each student has gained the knowledge and skills in the subject for their grade. They can then take the Scholastic Reasoning Test (SAT) or American College Testing (ACT) later in high school if they plan to go to college.

Mathematics Curriculum and Standards between Hong Kong and the United States

Table 1 shows that the aims of Mathematics education in both countries have some similarities, such as developing problem-solving skills and mathematical communication. However, Mathematics education in Hong Kong puts more emphasis on Mathematics outcomes and daily applications, while the United States focuses more on concepts and principles (such as equity, mathematics curriculum, teaching, learning and technology).

Table 1
Aims of Mathematics Education in the United States and Hong Kong

Country	Aims
United States	National Council of Teachers of Mathematics' standards (2000) Six Principles: 1. Equity: Teachers provide equal access of learning Mathematics for all students. 2. Curriculum: Teachers promote coherent and comprehensive curriculum for increasing the students' understanding of Mathematics. 3. Teaching: Teachers deliver Mathematics content to the student with effective teaching methods. 4. Learning: Teachers have to encourage students using facts, procedures and concepts, also develop students' abilities to face of challenge. 5. Mathematics instructional programs should include assessment to monitor, enhance, and evaluate the Mathematics learning of all students and to inform teaching. 6. Assessment: Teachers have to monitor and evaluate students' performance through assessment. 7. Technology: Teachers should use technology to increase students' understanding of Mathematics and prepare them to apply Mathematics knowledge in an increasingly technological world. Process standards 1. Students are able to value and connect all Mathematics concepts. 2. Students are able to reason and do proof with mathematics. 3. Students are able to solve Mathematics problems. 4. Students become confident to represent how to solve Mathematics problems. 5. Students become confident to communicate mathematically.
Hong Kong	Primary School: 1. Students are motivated to learn Mathematics, also develop good learning attitude and independent thinking. 2. Students develop logical thinking and problem solving skills through the processes of learning Mathematics. 3. Students grasp the basic mathematical knowledge and computation skills to foster the sense of number and spatial. 4. Students are able to apply Mathematics to solve daily problem. 5. Students develop their abilities to use Mathematics language as communication tool. 6. Students develop creativity, sense of pattern structure and shapes. Secondary School: 1. Students are able to communicate, reason, conceptualize mathematically and solving real-world Mathematics problems. 2. Students are able to operate number, symbols and other Mathematical objects efficiently, 3. Students develop the positive attitude towards Mathematics, also appreciate cultural aspect and aesthetic of Mathematics 4. Students develop the sense of number, symbol, measurement and pattern structure.

Survey Results and Findings

To get a comprehensive picture of mathematics achievement in both countries, middle school and high school mathematics teachers from different school districts in each country were asked to complete an online survey for this study. A total of sixty teachers responded to the survey − thirty participants each from the United States (US) and Hong Kong (HK). The questions focused on these areas: class meeting structure, pedagogy and learning assessment, student activities, beliefs in education curriculum and standards, and professional training. We summarized the results from the survey in the subsections below.

Class Meeting Structure

Figure 2 shows that almost all of the US students have mathematics classes that meet five times per week compared to just half in HK, while Figure 3 shows the distribution of the length of the classes (in minutes.) It appears that US students spread more time learning mathematics and with greater frequency. However, it is also a common practice in HK to have double class periods to compensate for less frequent meetings. Figure 4 reveals a significantly greater percentage of double class periods in HK compared to the US. These double periods allow more time to learn mathematics deeply, more time to work on problems and exercises and more time for discussion.

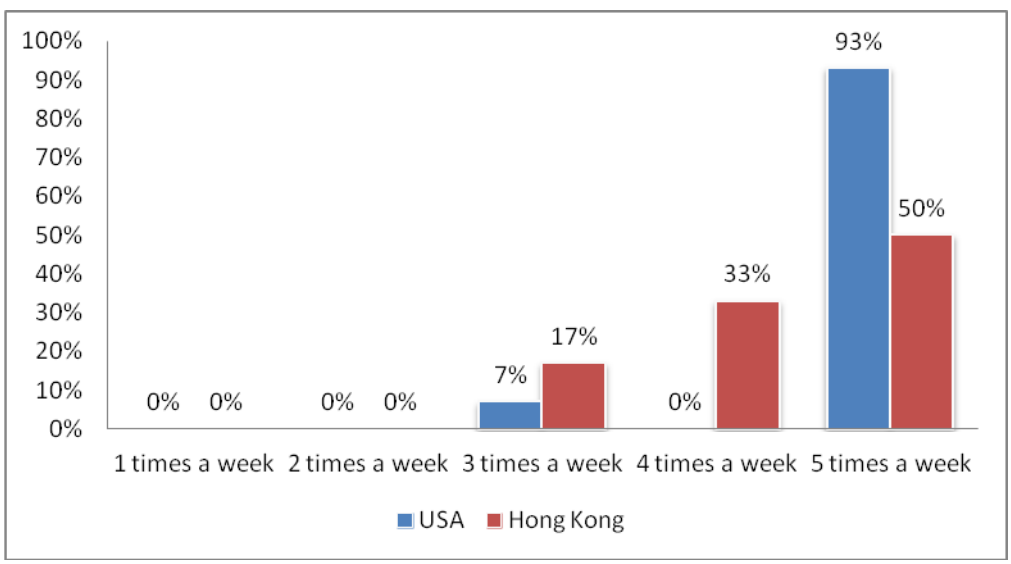

Figure 2: Frequency of students have mathematics lesson per week.

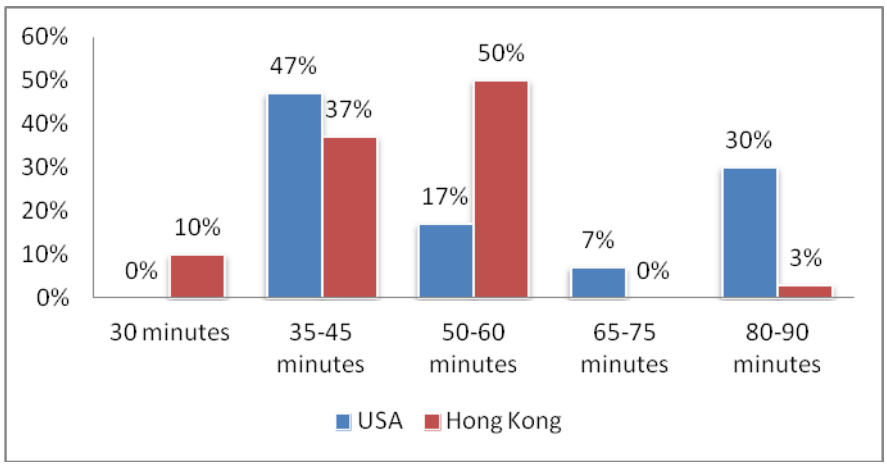

Figure 3. Length of time in a mathematics lesson (in minutes).

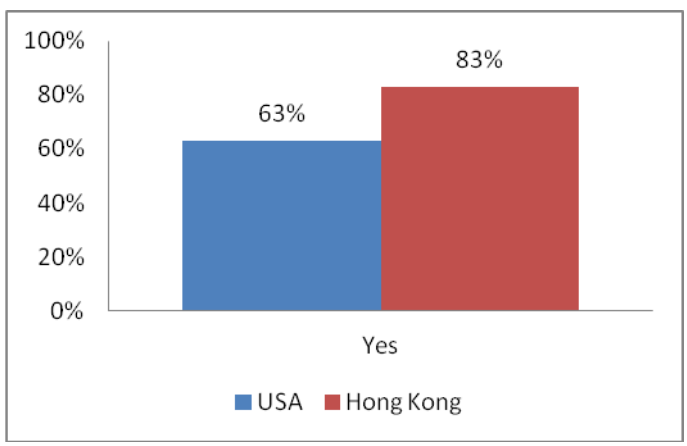

Figure 4. Percentage of double periods in mathematics lesson.

Teaching and Learning Strategies

In Table 2, we find that HK and the US are similar in delivering Mathematics to students. Both countries use lecture instruction, learning Mathematics by demonstration and practice methods, and have the same usage of class time. Where the two countries differ are in the use of technology, instructional environment and students' learning assessments.

Table 2
Comparison of teaching instruction between the United States and Hong Kong

United States	Hong Kong
• Demonstration method, practice method, lecture method and differentiated instruction • Use worksheets	• Demonstration method, practice method, lecture method and constructivist approach • Use textbooks
• Time use (percentage of class time): o Reviewing old content : 24% o Introducing new content: 57% o Summarizing new content: 19%	• Time use (percentage of class time): o Reviewing old content : 23% o Introducing new content: 59% o Summarizing new content: 18%
• Use of technology: o Website, Microsoft Office, Interactive whiteboards and graphing calculator	• Use of technology: o Microsoft Office, scientific calculator, Computer software and video
• Student-centered • Tests, short quizzes and observation	• Teacher-centered • Exams, test and short quizzes

Use of Calculator

Figure 5 shows a remarkable contrast in the percentages on the use of the graphing calculator as compared to the scientific calculator in the US and HK. The reason is that Hong Kong Examinations and Assessment Authority requires all candidates who take public examinations, i.e., HKALD, HKCEE and HKDSE, to use only approved scientific calculators, which excludes graphing calculators (HKEAA, 2013). Consequently, most HK students use scientific calculators in the classroom for solving mathematics problems and practicing for examination, even though graphing calculators are more powerful and versatile.

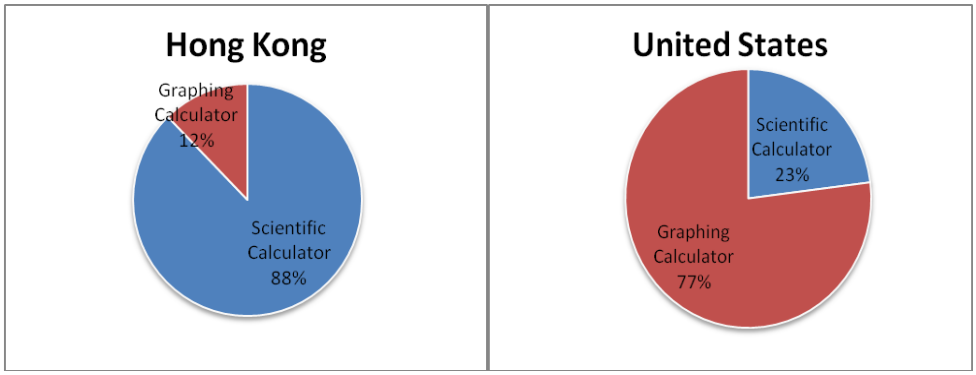

Figure 5. The percentages on the use of the graphing calculator as compared to the scientific calculator in the US and HK.

Instruction Environment

Figure 6 shows an interesting reversal in the distribution of those adopting teacher-centered versus student-centered strategies between HK and the US. Many HK teachers had to resort to the teacher-centered approach due to large class-sizes of over thirty students (Figure 7). It is understandably difficult for teachers to group more than thirty students together by interest or ability, and then supervising them to conduct the different group activities. It is much easier to manage a large class if all students in the classroom are just taught the same material.

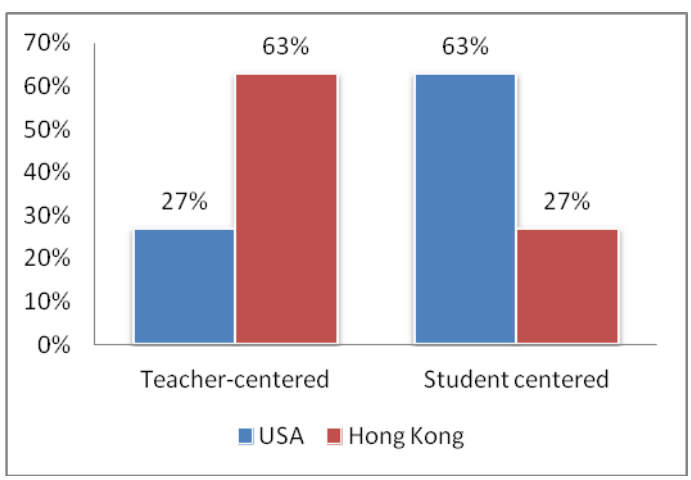

Figure 6. Distributions of teacher-centered and student centered pedagogy.

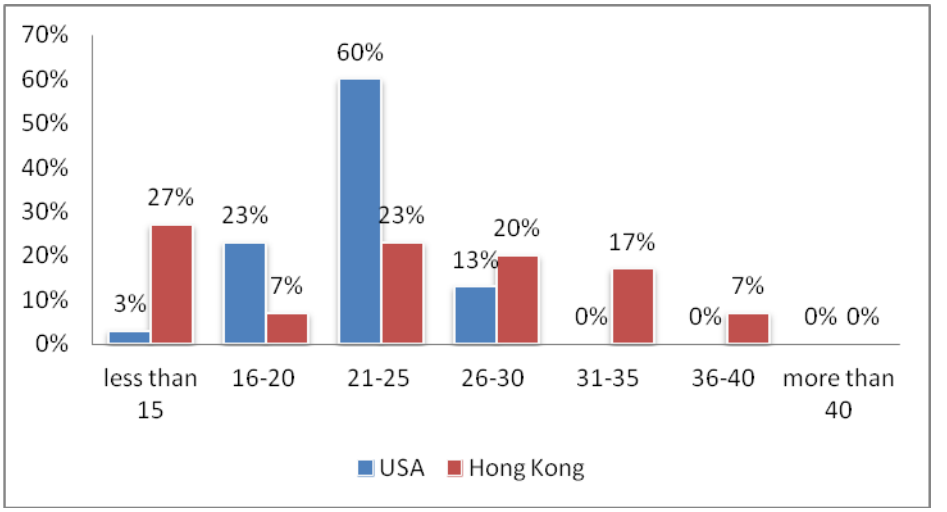

Figure 7. Distribution of average number of students in Mathematics lesson.

On the other hand, 86 percent of classrooms in the US have less than twenty-five students. Therefore, more teachers in the US are able to adopt student-centered strategies because of the smaller class size. In a student-centered classroom, students are dynamically grouped by their learning styles, readiness and interests for flexible grouping and cooperative learning. They are provided with hands-on experience, discovery pursuits and group activities. In addition, they are also encouraged to participate in class discussion. This difference in the teaching approaches is further revealed in figure 8, where the percentages of the use of group projects and class discussions in the US are significantly greater than in HK.

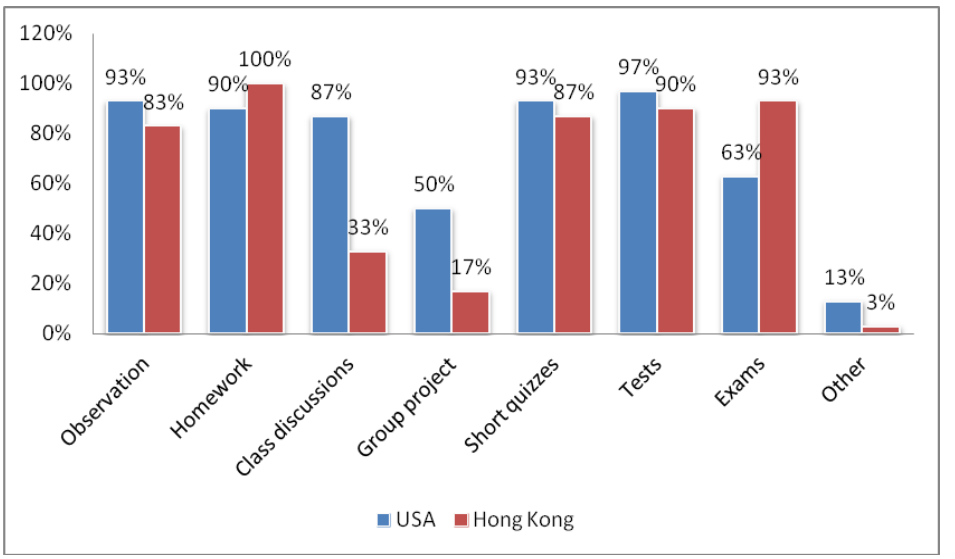

Figure 8. Distributions of learning assessment between the United States and Hong Kong.

Learning Assessment

Figure 8 also shows a significant difference between the US and HK in the percentages of giving more intensive exams in the classroom (93% in HK and 63% in the US).

In Hong Kong, like other Asian countries, high-stakes testing drives the education system (Romanowski, 2006). As mentioned earlier, HK students not only have at least a mid-term exam and a final exam every school year, but they also have five standardized assessments and examinations from Primary and Secondary school. The results of these assessments and exams are then utilized for students to decide to enroll in better schools or to continue their studies in higher education. Therefore, by extension, HK teachers would put more emphasis on exams in their classroom.

The United States also has its own form of high-stakes testing, whereby students in grades 3 to 8 are required yearly assessments and the results affect the school districts receiving federal funding. Consequently, the school curriculum might focus only on the testing materials, and students study only these materials to pass the test (Yeh, 2006).

This difference in motivations might help explain the achievement gap in mathematics between the US students and HK students: high-stakes testing narrows the curriculum to facilitate the US students to pass yearly assessments while high-stakes testing prompts HK students to work harder to achieve future personal success.

Mathematics-Related Student Activities

In Figure 9, the percentage of participating in Mathematics Olympiad training from HK students is significantly higher than in the US. In Hong Kong, there are only seven Mathematics competitions for students, namely, the Hong Kong Mathematics Olympiad, the Hong Kong Mathematical High Achievers Selection Contest, International Mathematical Olympiad Preliminary Selection Contest, Pui Ching Invitational Mathematics Competition, Inter-school Mathematics Contest, Sing Yin Secondary School Invitational mathematics Competition and Primary Mathematics World Competition (Education Bureau, 2011). Most HK students will be focused on participating in Hong Kong Mathematics Olympiad and International Mathematical Olympiad because they are more famous (and prestigious) than other competitions. In the United States, there are eighteen national competitions for middle school students and at least thirty for high school students, which provide more options for the US students (Art of Problem Solving, 2014).

Although HK students do not seem to have much interest in math clubs, tutoring and workshops as compared to US students, they do participate in Math Week celebrations, while the US does not have any participating

students show that. In Hong Kong, Math Week is a very popular event where teachers and senior students organize and implement Mathematics activities for the whole school for a week. These activities may include Math Fair, Math Games, Sudoku, Mathematician Exhibition, Inter-class Math Quiz Competition and others.

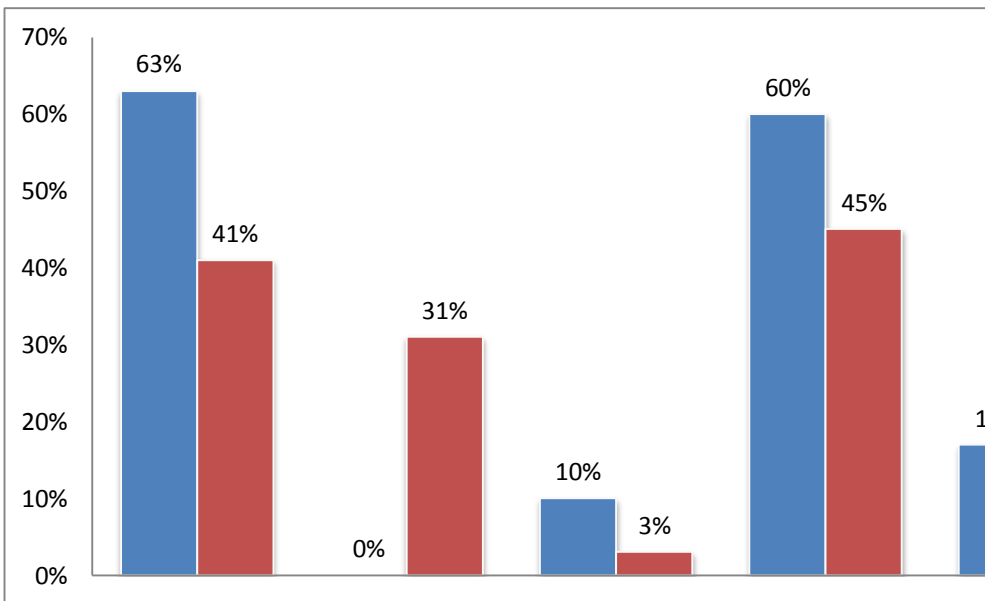

Figure 9. Distribution of mathematics related activities in the United States and Hong Kong.

Beliefs in the Mathematics Education Curriculum and Standards

In Hong Kong, mathematics curriculum provides specific leaning objectives and examples in each unit while in the US, curriculum is more flexible, which means it does not provide any examples or details to match the standard. Consequently, Figure 10 shows that a large majority (70 percent) of HK Mathematics teachers agree that their current Mathematics curriculum and standards have a clear and a rigid framework, while in the US only 40 percent agree. Moreover, half of the US teachers consider the current Mathematics curriculum and standards to be somewhat difficult for their students, as shown in Figure 11.

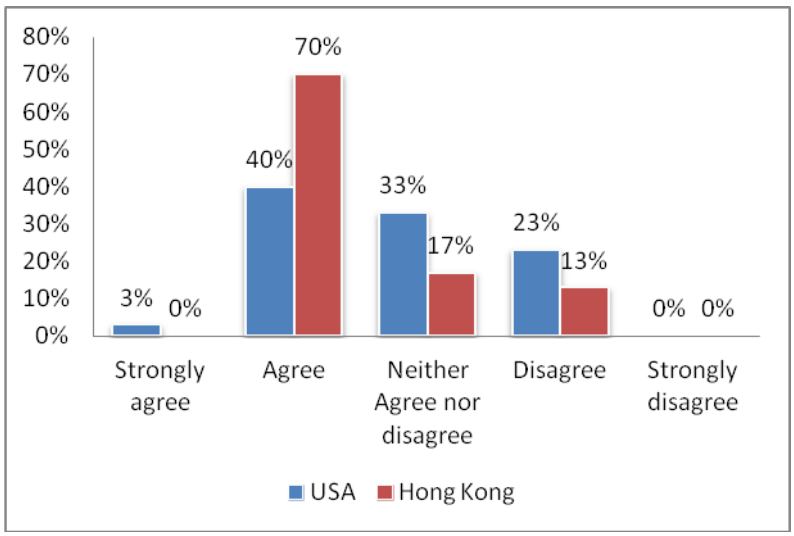

Figure 10. Distribution of teachers' belief that the mathematics curriculum and standards from the Education Department have a clear and a rigid framework between the United States and Hong Kong.

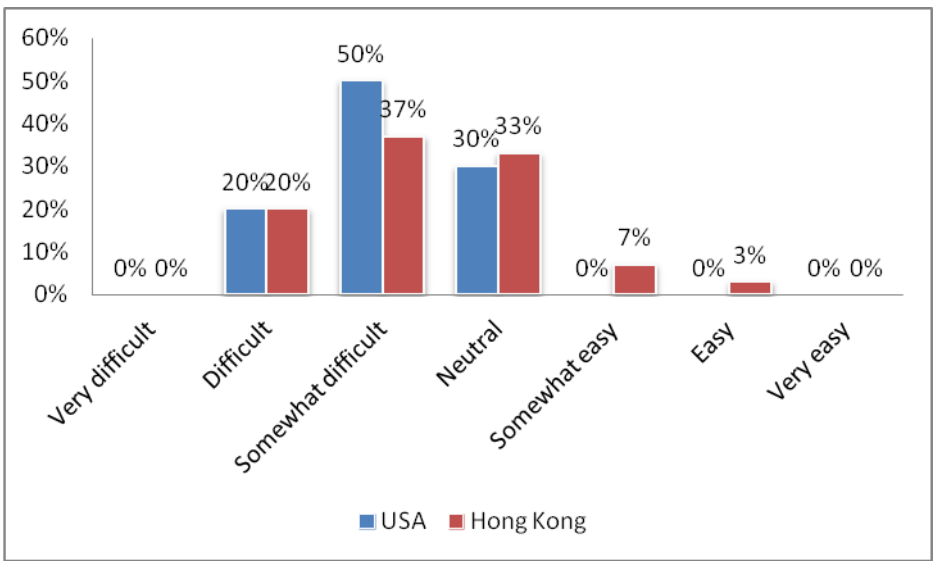

Figure 11. Distribution of teachers describing current mathematics curriculum and standards between the United States and Hong Kong.

Professional Training

In Figure 12, we see that most teachers in both countries participated in professional training and seminars during the 2012-2013 school year with similar percentages. However, we see wider differences in the distribution of the number of trainings, workshops and seminars that they have attended, as

shown in Figure 13. In Hong Kong, most of the teachers participated in fewer number of workshops as compared to the US teachers, and these HK teachers chose to attend workshops focusing on "learning and teaching strategies" and "mathematics curriculum", as shown in Figure 14. With the fewer number of workshops that HK teachers attended, it is not surprising that they chose these focus areas because these are related to each other in designing the lessons. Teachers have to use mathematics curriculum as standard, and they use different teaching strategies to improve or enhance students' mathematics knowledge and skills. Figure 14 also supports the observation that since US teachers have attended a greater number of workshops, they were able to participate across all focus areas in consistently higher percentages than HK teachers.

American teachers have attended more workshops because they are usually required to attend most of the in-service trainings that are provided by their school districts. In addition, some educational organizations and associations also provide training workshops for the teachers who are interested in a specific area, although teachers may have to pay for the membership of these organizations and the fee for the workshops. The Hong Kong Education Bureau aprovides free in-service training to HK teachers. Moreover, some educational organizations and associations in HK also offer training for the teachers, but they also have to pay for the costs of these workshops as in the US.

With these similar situations, why is there a fewer number of workshops that HK teachers have attended compared to the US? Although the workshops may be free in HK, the process involved in applying and registering for these workshops is rather complicated. First, teachers need to apply for the workshops using the online system from the Education Bureau website. Then, the school principal or supervisor has to approve or reject the application online based on the teachers' schedule, the relevance of the workshop to the subjects that teachers teach and their school needs. If teachers get approved by the school, they will subsequently receive an email to register for the workshops. The entire process may take a very long time, and with a possibility of their applications being rejected anyway, some teachers are just not very enthusiastic about applying for these free workshops from the Education Bureau. Also, the length of these training workshops can be half day, a whole day, or several weeks, from Monday to Sunday. However, some schools only encourage teachers to take workshops or the weekend so that it will not affect the regular class meetings, thereby limiting the number of workshops that they can participate in.

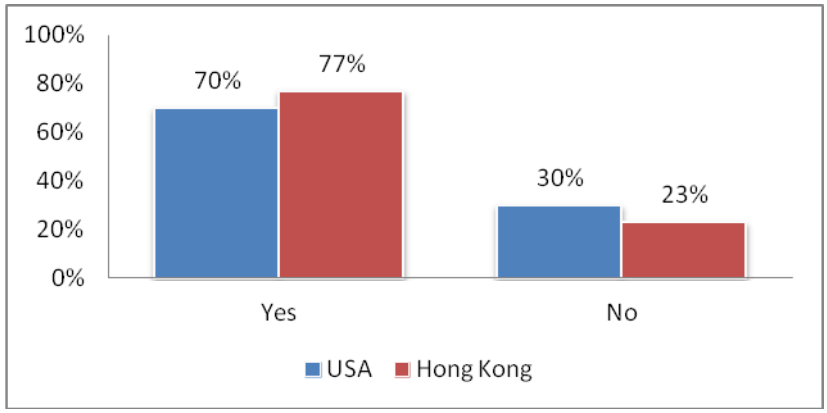

Figure 12. Participation in professional trainings and seminars for Mathematics teachers during the 2012-2013 school year.

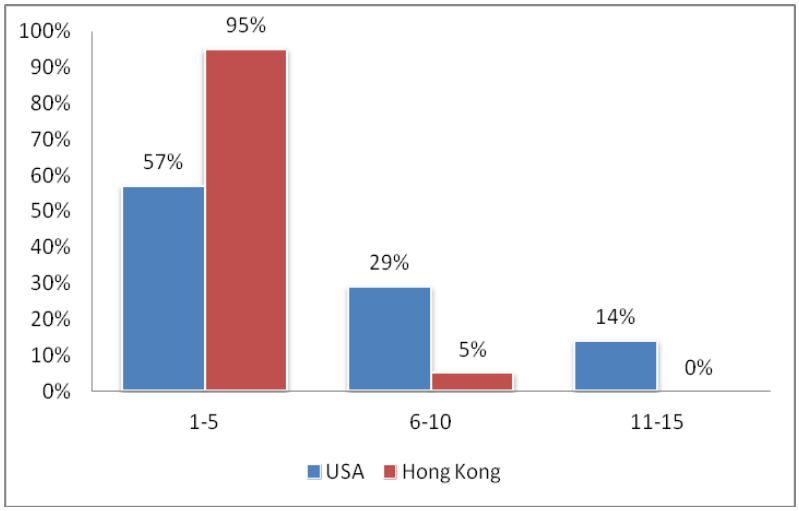

Figure 13. Distribution of the number of trainings, workshop and seminars that teachers have participated in during the 2012-2013 school year.

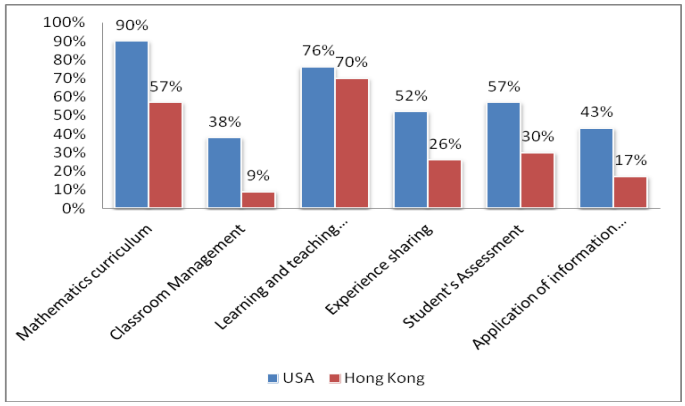

Figure 14. Distribution of focus areas of trainings, workshop and seminars that teachers attended.

Conclusion

According to the PISA reports, Hong Kong consistently transcends all expectations in mathematical performance in international standardized tests while the United States continues to lag behind. We developed this study to determine if we can identify any significant contributing factors to the large performance gap between HK and the US. We found three plausible reasons:

First, Hong Kong children begin pre-school education at least two years earlier than children in the United States. Therefore, some topics are already introduced into HK's curriculum two years earlier than the international average. Second, our survey shows a significant difference between the US and HK teachers in the percentages of giving more intensive exams in the classroom (93% in HK and 63% in the US). Its 'exam-centric' system prompts HK students to maximize their abilities to cope with numerous examinations including internal examinations and public examinations. Moreover, high-stakes testing drives HK students to work harder to get high scores and achieve future personal success. Third, the characteristics and differences of the Mathematics education system in both countries may also affect the students' learning performance. Based on the results of our survey, the US teachers usually apply a differential approach or student-centered approach since the class size is smaller than HK. However, the regular class size is at least 30 students in HK. Therefore, HK teachers choose teacher-centered approaches to facilitate classroom management. Hong Kong also emphasizes the use of textbooks while the US is more flexible in their use of textbooks.

Hong Kong students who receive teacher-directed instruction are expected to listen to lectures, take tests, and do seatwork. They are also divided according to various measures of ability which increases inequalities over time. There is no personalization centered on the needs of the student. However, they have more opportunities to practice Mathematics problems deeply to cope with the internal and public examinations.

Conversely, student-centered learning in the US provides a variety of discovery activities, group discussion, cooperative learning projects and hands-on activities for students to develop a new understanding of mathematics concepts and application. However, hands-on activities are time-consuming, teachers may run out of time when teaching the lesson and they may not have enough time to discuss Mathematics problems with students deeply. The student-centered approach helps students to explore Mathematics concepts widely, but not as deep as using the teacher-centered approach.

Note that the continuous curriculum and system reform in both countries may reduce the performance gap in the future. After 2012, Hong Kong shifted away from its 'exam-centric' system which reduces the number of subjects and exams that senior secondary students should take under the old academic structure. The policy-makers believed that the new "3-3-4"

education system can help students develop their self-study skills and life-long learning attitude through cross-curricular and inquiry-based methodologies. On the other hand, a new system creates many controversies itself, such as how to teach a 4 year syllabus in 3 years but still maximize the students' abilities and performance. This new education system brings unknown future impacts in learning Mathematics in Hong Kong, while the United States is certainly putting all efforts in improving its mathematics education so it is more competitive in the international mathematics community.

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Authors:

Sui-Yan Chan
Kean University
Email: chansu@kean.edu

Pablo Zafra
Kean University
pzafra@kean.edu