Mathematics Education in Singapore: How can Mathematics Education in Singapore inform Mathematics Education in US

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The purpose of this article is to examine how the mathematics education system of the Republic of Singapore can benefit the United States. U.S. students had consistently ranked poorly as compared with their peers in many other nations on international studies, while Singapore has consistently scored very well. The intention of the article is to inform and improve mathematics education in the United States by analyzing the literature on Singapore’s educational system and exploring aspects that may be helpful to U.S. education.
Introduction

There had been an ongoing crisis in mathematics education in the United States in recent years (Carson & Rowland, 2007; Gott, 2007; Klein et al., 2005; Starkman, 2007; Thomas B. Fordham Foundation, 1998). U.S. students had consistently ranked poorly as compared with their peers in many other nations, as apparent in the Program for International Student Assessment (PISA, 2013) and Trends in International Mathematics and Science Study (TIMSS, 2013a). PISA is an assessment of 15-year-old achievement in mathematics, science, and reading, which has been conducted every three years beginning in 2000 and continuing in 2003, 2006, 2009, and 2012. On average, PISA results had indicated that U.S. students scored below the average among Organization for Economic Cooperation and Development (OECD) countries. Results from the 2012 assessment indicated that U.S. students had scored below average compared to participant nations, while the Republic of Singapore consistently ranks at the top of the participating nations (PISA, 2013).

The TIMSS is an international assessment of fourth and eighth grade students’ achievement in mathematics and science content knowledge that has been conducted every four years beginning in 1995 and continuing in 1999, 2003, 2007, and 2011. While the United States has been improving its rankings over the TIMSS studies, it had continued to rank lower than other participating nations (Garelick, 2006; Ginsburg, Leinwand, Anstrom, & Pollock, 2005) and can be considered a “second tier” nation in...
mathematics (TIMSS, 2013b; TIMSS, 2013c; TIMSS, 20013d; TIMSS, 2013e). In the first implementation of the study in 1995 it was found that U.S. eighth grade students ranked 28th in mathematics out of 41 participating countries and regions (Beaton et al., 1996). U.S. eighth grade students ranked 19th in mathematics out of 38 participating countries and regions in the 1999 study (TIMSS, 2013b), and ranked 15th out of 45 participants in the 2003 study (TIMSS, 2013c). Singapore, however, has consistently ranked first in mathematics in the first three implementations (1995, 1999, and 2003) of the TIMSS (Beaton et al., 1996; TIMSS, 2013b; TIMSS, 2013c). Gonzales et al. (2004) indicated that in the 2003 TIMSS study it was found that 45% of eighth grade students in Singapore scored at the advanced level in mathematics. In the United States, only 7% of eighth grade students scored at the advanced level in mathematics. Other countries and administrative regions to consistently score very well in mathematics include Hong Kong, Japan, South Korea, and Taiwan.

The 2007 results of the TIMSS revealed that Singapore, while no longer ranking first in mathematics for eighth grade students, still ranked very highly with only Taiwan and South Korea ranking slightly higher. However, there was no statistically significant difference between the top five scoring nations in 2007. U.S. eighth grade students were found to rank 9th in mathematics out of 48 participants, with a statistically significant lower score than only the five highest achieving countries and administrative regions, Taiwan, South Korea, Singapore, Hong Kong, and Japan (TIMSS, 2013d). In 2011 the United States continued to rank 9th, just as in 2007, for 8th grade mathematics
performance out of 42 participating countries and regions, while Singapore moved up to 2nd place, just behind South Korea but ahead of Taiwan (TIMSS, 2013e). The same five countries and regions that had significantly higher scores in 2007 than the United States continued to score higher than the United States, with the addition of Russia having a statistically higher score than the United States (TIMSS, 2013e).

The steady improvement of the eighth grade mathematics rankings has continued in the United States since the initial 1995 TIMSS study. There was a significant difference between eighth grade mathematics scores in the United States in 1995 ($M = 492$) and 2011 ($M = 508$) (TIMSS, 2013f). However, despite a much lauded improvement, the United States still lags behind more than high-performing East Asian nations and administrative regions, in addition to Russia. Further, 2011 results indicated while 48% of eighth grade students in Singapore scored at the advanced level in mathematics, only 7% of U.S. eighth grade students scored at the advanced level (TIMSS, 2013g). However, it would be remiss not to acknowledge that U.S. students in affluent suburban schools scored nearly as well as students in Singapore and the gap between high and low performing U.S. schools is greater than the gap between the U.S. and high achieving nations (Brown & LaVine Brown, 2007). China, for example, only uses data from Shanghai and Hong Kong in the Pisa results, which tends to skew scores upward.

Teacher preparation in mathematics education has recently been reported as inadequate compared to other higher achieving countries on the TIMMS, particularly for
middle school teacher preparation (Babcock et al., 2010). Babcock et al. (2010), in the Teacher Education and Development Study in Mathematics (TEDS-M), found that in many top achieving countries pre-service middle school teachers had about half of their preparation in mathematics content and half in pedagogy. In the U.S. this was about 40% in content and 60% in pedagogy. Further, on average about 90% of the highest achievement nations had pre-service middle school teachers taking linear algebra and a full year of calculus while about two-thirds of U.S. middle school pre-service teachers had linear algebra and slightly more than half of them had a full year of calculus. Babcock et al. (2010) referred to these courses as gateway courses to higher level mathematics. Further, they found that middle school mathematics teachers in the United States were much less adequately prepared than were secondary school teachers. Moreover, they found that quality in teacher preparation varied greatly throughout the United States.

The U.S. Commission on National Security in the Twenty-First Century (2001) reported that inadequacies of U.S. education pose one of the biggest threats to the national security of the United States. There is a need to improve U.S. education, and given the high mathematics achievement found in Singapore schools, learning more about the education model in Singapore could inform and improve U.S. education. The TIMSS 1999 Video Study compared teacher practice in seven countries: Australia, Czech Republic, Hong Kong, Japan, Netherlands, Switzerland, and the United States (Heibert et al., 2003; Leung, 2005), but did not include observations in the highest achieving nation,
Singapore. VanTassel-Baska et al. (2008) examined teacher practices in both Singapore and the United States in secondary classrooms with gifted students. More observational research is necessary to understand what typical teachers in Singapore are doing in their classrooms and how this could inform instruction in the United States. Cathy Seeley, former president of the National Council of Teachers of Mathematics (NCTM) said:

But we have to look beyond their [Singapore’s] textbooks to determine what these lessons are. The more we learn about what is being done in the Asian Rim countries, the more it appears that mathematics is not taught in the same way in which we have traditionally taught mathematics in this country (Seeley, 2005).

Observing how mathematics is taught in actual Singapore classrooms goes well beyond simply comparing mathematics textbooks used in the United States with those used in Singapore.

A Brief History of Singapore: Republic and Education

Sir Thomas Raffles established Singapore as a trading post for the British East India Company in 1819. It served as a major trading and military center of the British Empire during the 19th and early 20th Centuries. During World War II the Japanese occupied the city before it was returned back to the British after the end of the war. In 1963 Singapore declared independence from the United Kingdom to join 13 other states in the region to create Malaysia. On August 9, 1965 Singapore left Malaysia to become the Republic of Singapore.
Singapore is a city-state nation and one of the smallest countries in the world by area, and about the size of New York City by land. It has a population over five million people, making it considerably larger than Los Angeles, but smaller than New York, in terms of population. About 75% of the population is ethnic Chinese, with the remaining population consisting primarily of ethnic Malaysians and Indians.

Since Singapore’s independence in 1965, it has gone from being a poor nation to being among the richest nations in the world, based on per capita income. It is considered an astonishing success, due to its lack of natural resources, attributed to its education system that produced a highly educated population. The research division of Citigroup, a major financial service corporation, places Singapore at the top of list of countries for per capita GDP (PPP) every decade until 2050, the extent of Citigroup predictions (Buiter & Rahbari, 2011). Interestingly, by 2030 Citigroup predicts the top four countries or administrative regions will be Singapore, Hong Kong, Taiwan, the United States, and South Korea. By 2040 South Korea is predicted to switch places with the United States (Buiter & Rahbari, 2011).

Instruction in Singapore’s elementary schools is primarily conducted in English, which continues to be the primary language of instruction in later grades in mathematics and science. The Ministry of Education is the governmental department charged with the responsibility of overseeing the centralized school system and creating the curriculum. High stakes standardized testing is used at the end of primary and secondary education
(Ginsburg et al., 2005). Teacher preparation is solely conducted by the National Institute of Education (NIE), an autonomous part of Nanyang Technological University (NTU).

**Singapore Mathematics Textbooks and Method**

After the 1999 TIMSS had been conducted, it was very clear that Singapore was excelling in mathematics among the international community after ranking first in mathematics for two consecutive studies (Beaton et al., 1996, TIMSS, 2013a). At the turn of the 21st Century, a publishing company, Singapore Math Inc., published mathematics books based upon the Singapore method of mathematics instruction in the United States. These books were based upon the mathematics textbooks used in Singapore, but adapted for a U.S. audience. For example, in Singapore, like most of the world, the metric system is used exclusively. The U.S. version of the series focuses on both metric and the U.S. customary system of measurement. Problems involving money use U.S. dollars in the U.S. version. Since school instruction in Singapore is conducted in English, this makes the transition from Singapore to the United States even easier.

Singapore Math books are usually thinner than their traditional, and sometimes reform-based, U.S. counterparts, and they cover fewer topics, but in greater depth (Ginsburg et al., 2005; Schmidt, Houang, & Cogan, 2002). The U.S curriculum has been often been described as “a mile wide and an inch deep” (Schmidt & Houang, 2007). Purportedly, fewer topics in greater depth may lead to better understanding and better adaptability when confronted with unfamiliar concepts. A major problem is that U.S. textbook publishers must accommodate 50 states and their standards, whereas Singapore
has a centralized system that enables the books to have more focus. The U.S. has moved toward a common national curriculum with the Common Core Standards, but more differences persist between individual U.S. states as compared to small-sized Singapore. Singapore textbooks are well aligned with their national framework, which is not always true in the United States. U.S. students comparatively learn too many topics with not enough understanding or depth for each topic covered. In Singapore, fewer topics are covered, but mastery is emphasized. For example, in early grades the highest achievement countries on the TIMSS cover about four to six topics per year, compared to 20 topics in the United States (Schmidt, 2008). In later grades, some U.S. states cover about twice as many topics as does Singapore (Ginsburg et al., 2005). Schmidt and Houang (2007) suggested more coherence for the U.S. curriculum. A coherent curriculum would mean that there is a logical flow of topics in sequence that are well articulated and organized (Schmidt, Houang, & Cogan, 2002). Video analysis demonstrated that in “East Asian classrooms more advanced content was covered and the lessons were more coherent” (VanTassel-Baska, 2008, p. 342). Specially, this was conducted in Hong Kong (Leung, 2005). Ginsburg et al. (2005) said that U.S. education “lacks a centrally identified core of mathematical content that provides a focus for the rest of the system” (p. ix). Schmidt (2008) said, “The single most important result of the Third International Mathematics and Science Study (TIMSS) is that we now know that student performance is directly related to the nature of the curricular expectations.”
The Singapore mathematics books do not “spiral” in the same way U.S. books do (Ginsburg et al., 2005). The idea is that the concepts are taught well enough not to revisit in the same manner. Instead, if a concept is spiraled in Singapore mathematics, it is explored in a deeper manner, not taught over again as it is in the United States (Schmidt, Houang, & Cogan, 2002). Singapore mathematics books typically do not have colored graphics, but instead ground basic mathematical ideas through pictures such as the comparisons of bars method (Hoven & Garelick, 2007). This method involves using bars to help understand mathematical concepts. Garelick (2006) provides an example: Mary and Bill have $10 between them. Mary has $2 more than Bill. How much money does each person have? Given this situation, students will set up two bars, one drawn directly above the other, representing Bill and Mary’s money separately. Mary’s bar extends for $2 more than Bill’s bar. This means that other than the $2 extension, their bars are the same length. Students then can see that Bill has $4 and Mary has $4 + $2 = $6. According to Ginsburg et al. (2005), “Singapore’s textbooks build deep understanding of mathematical concepts through multistep problems and concrete illustrations that demonstrate how abstract mathematical concepts are used to solve problems from different perspectives” (p. xii).

The interesting aspect is that in the United States the Singapore mathematics books are considered to be an alterative to reform-based mathematics textbooks currently used in the United States. Singapore mathematics books are championed by the “back to the basics” proponents, and are seen as promoting traditional mathematics education.
Interestingly, the Singapore mathematics books teach mathematics from a conceptual, in addition to procedural, perspective while teaching for understanding. They engage students in the problem solving process (Hoven & Garelick, 2007). Ginsburg et al. (2005) said, “The Singapore texts are rich with problem-based development in contrast to traditional U.S. texts that rarely get much beyond exposing students to the mechanics of mathematics and emphasizing the application of definitions and formulas to routine problems” (p. xii). According to Singapore’s Ministry of Education (2001), “The primary aim of the mathematics curriculum is to enable pupils to develop their ability in mathematical problem solving” (p. 5). It would appear that Singapore mathematics books conform to the spirit of reform-based constructivist perspectives with their emphasis on student derived knowledge and understanding through constructivism. However, certain areas such as data analysis, statistics, and probability are left out of the Singapore mathematics books (Garelick, 2006). This means that state, Common Core, and NCTM standards will not be accomplished using the Singapore mathematics books exclusively, and thus supplemental materials are needed. Further, real-life applications and problems that require trial and error are not found in Singapore mathematics books as they are found in their U.S. counterparts (Garelick, 2006). Thus, more supplemental materials are needed.

**Singapore Mathematics Pilot in the United States**

Pilot programs using mathematics textbooks based upon the Singapore system have been conducted in over 80 school systems in the United States (Ginsburg et al.,
One of the best known pilots of the Singapore mathematics program occurred in four schools in Montgomery County, Maryland (Garelick, 2006). According to Garelick (2006), there were mixed results from the use of the Singapore mathematics program with some schools performing the same or worse as before the Singapore mathematics program was piloted. Two Maryland schools had their students outperform control groups in achievement (Ginsburg et al., 2005). However, only one school, College Gardens, continued to use the Singapore mathematics program into the second year. After the second year Montgomery County ended the program. A major reason given for the failure of this program was the lack of support for teachers using it. The Singapore mathematics program requires teachers to have a deeper understanding of mathematics than U.S. teachers typically do. In order to succeed, more preparation for U.S. teachers would be necessary. Furthermore, as mentioned previously, the Singapore mathematics books lack some topics that are part of state, Common Core, and NCTM standards such as data analysis, statistics, and probability. These areas had to be supplemented with additional materials that were a further cost to the schools.

More recently the South River Primary School and South River Elementary School in South River, New Jersey, has employed the Singapore mathematics program (Hoven & Garelick, 2007). According to Hoven and Garelick (2007), teachers in this district first had difficulty with the transition given the slower and more in-depth method of teaching. The assistant superintendent in South River claimed that an advantage of the Singapore mathematics program was that it teaches for mastery so there is no need to re-
teach the same material year after year. Another advantage is that the Singapore mathematics method focuses on essential mathematics skills as recommended in the NCTM Focal Points (2006).

It was found that in Patterson, New Jersey, an urban school district, that students were transitory in moving around school to school. Thus, many moved in and out of the Singapore system and this proved to be problematic (Ginsburg et al., 2005). Similar to the case in Maryland, additional topics not covered in the Singapore books had to be supplemented by additional materials to address state standards.

The Singapore mathematics program was specifically successful in the North Middle Regional School District in Massachusetts (Ginsburg et al, 2005). A much higher proportion of students using the Singapore mathematics method placed into the advanced mathematics level as compared with a control group who did not use the Singapore mathematics method. The state superintendent in Massachusetts has called on other school districts in the state to consider the Singapore system.

Mathematics Achievement and Teaching in Singapore and East Asia

As previously mentioned, Singapore has consistently placed first in mathematics achievement in the first three TIMSS studies (Beaton et al., 1996, TIMSS, 2013a). In the most recent TIMSS, Singapore ranks third, but only slightly behind the Taiwan and South Korea. Students in several East Asian countries and administrative regions also consistently rank highly on the TIMSS. Further, as stated earlier, a much higher percentage of students scored in the advanced level in mathematics than did students in
the United States in recent studies such as the 2003 (Gonzales et al., 2004) and 2007 studies. One variable to consider is teaching practice in the classroom.

VanTassel-Baska et al. (2008) examined teacher practices in secondary classrooms with gifted students in both Singapore and the United States. It was found that Singapore teachers were more effective than their U.S. counterparts. They found a statistically significant difference between teachers in Singapore and the United States in the areas of curriculum delivery and planning, accommodation for individual differences, and critical and creative thinking strategies, with Singapore teachers outperforming U.S. teachers. Despite U.S. teachers generally having more experience and higher academic degrees than Singapore teachers in the VanTassle-Baska et al. (2008) study, teachers in Singapore had higher content knowledge (Ginsburg et al., 2005), as found in Ma’s (1999) comparative study of Chinese and U.S. teachers. This is supported by Leung (2005), who studied teachers in Hong Kong and Japan, two other places with students achieving highly on international examinations.

Ingersoll (2007) claimed that U.S. teacher quality is a major problem in the United States. Interestingly, it was found that many primary school teachers in Singapore do not have four-year college degrees, but yet have a solid foundation in basic mathematics. However, Ginsburg et al. (2005) found that teachers in the United States have mathematical content knowledge that is much below that of teachers in Singapore. This is alarming considering the need for highly qualified teachers called for by No Child Left Behind (NCLB) in the United States. Elementary school teachers in Singapore take
about twice as many mathematics courses as do elementary school teachers in the United States during teacher preparation. Furthermore, teaching in Singapore is more highly regarded as a profession than it is in the United States (Ginsburg et al., 2005; Ingersoll, 2007). Lai, McCallum, and Soto-Johnson (2011) found that a teacher preparation gap could be a variable responsible for the student achievement gap between East Asia and the United States.

Leung (2005) cited video analysis from the TIMSS 1999 Video Study that found students from Hong Kong and Japan studied mathematics problems that were longer than in western nations including the United States. More time was dedicated to new material in Hong Kong and Japan as compared to the new instruction time in the United States. Students in Hong Kong were exposed to more advanced mathematical instructional content, were more engaged, and lessons were more coherent, fully developed, and of better overall quality than in the United States. More proofs were done in Japan and problems were of more complexity than in the United States. Leung (2005) speculated that high content knowledge of teachers and use of proof and mathematical language are contributing factors to success rates in Hong Kong and Japan. Further, Leung (2005) addressed the cultural issue of respect for a knowledgeable teacher found throughout East Asia. A strong content knowledge is paramount to receiving respect from students, which could lead to motivation for teachers to be competent in their area. Leung (2005) cautioned that each country’s culture influences learning and one cannot simply transplant practices from one culture to another without considering these differences.
Considerations and Conclusions

Cultural issues may have a big impact on learning in Singapore as compared to the United States that will not be addressed in this study (Leung, 2005). Tsui (2007) argued that differences could be due to social and environmental factors. Singapore generally has a more homogenous student population than does the United States, which makes transferability between Singapore and the United States complicated. Singapore students are considered to be highly motivated academically, and families in Singapore place a great emphasis on education (Ginsburg et al., 2005). Another variable to consider is teacher preparation. Teachers in Singapore have higher content knowledge than do teachers in the United States (Ginsburg et al., 2005; VanTassel-Baska et al., 2008). Further, Singapore is a very small country with a centralized education system, as compared with the large population and decentralized system in the United States. However, given the growing influence of the NCTM Standards (2000) at the state level over the last several decades, and the adoption of more states of the Common Core State Standards for Mathematics in the United States, the trend is that U.S. education is becoming more centralized than it has been in the past. Variables such as culture and teacher preparation should be investigated in subsequent studies.

While there are major differences between the two countries, it’s likely that understanding the educational system in Singapore could help inform U.S. education, particularly in mathematics. Culture undoubtedly plays an important role, but individual strategies used in Singapore, and other high achieving nations, may be helpful for U.S.
education. More studies should be conducted on the Singapore system with effectual aspects integrated into the U.S. system where relevant and possible.

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VanTassel-Baska et al. (2008) examined teacher practices in secondary classrooms with gifted students in both Singapore and the United States. It was found that Singapore teachers were more effective than their U.S. counterparts. They found a statistically significant difference between teachers in Singapore and the United States in the areas of curriculum delivery and planning, accommodation for individual differences, and critical and creative thinking strategies, with Singapore teachers outperforming U.S. teachers. Despite U.S. teachers generally having more experience and higher academic degrees than Singapore teachers in the VanTassle-Baska et al. (2008) study, teachers in Singapore had higher content knowledge (Ginsburg et al., 2005), as found in Ma’s (1999) comparative study of Chinese and U.S. teachers. This is supported by Leung (2005), who
studied teachers in Hong Kong and Japan, two other places with students achieving highly on international examinations.

Ingersoll (2007) claimed that U.S. teacher quality is a major problem in the United States. Interestingly, it was found that many primary school teachers in Singapore do not have four-year college degrees, but yet have a solid foundation in basic mathematics. However, Ginsburg et al. (2005) found that teachers in the United States have mathematical content knowledge that is much below that of teachers in Singapore. This is alarming considering the need for highly qualified teachers called for by No Child Left Behind (NCLB) in the United States. Elementary school teachers in Singapore take about twice as many mathematics courses as do elementary school teachers in the United States during teacher preparation. Furthermore, teaching in Singapore is more highly regarded as a profession than it is in the United States (Ginsburg et al., 2005; Ingersoll, 2007). Lai, McCallum, and Soto-Johnson (2011) found that a teacher preparation gap could be a variable responsible for the student achievement gap between East Asia and the United States.

Leung (2005) cited video analysis from the TIMSS 1999 Video Study that found students from Hong Kong and Japan studied mathematics problems that were longer than in western nations including the United States. More time was dedicated to new material in Hong Kong and Japan as compared to the new instruction time in the United States. Students in Hong Kong were exposed to more advanced mathematical instructional content, were more engaged, and lessons were more coherent, fully developed, and of
better overall quality than in the United States. More proofs were done in Japan and problems were of more complexity than in the United States. Leung (2005) speculated that high content knowledge of teachers and use of proof and mathematical language are contributing factors to success rates in Hong Kong and Japan. Further, Leung (2005) addressed the cultural issue of respect for a knowledgeable teacher found throughout East Asia. A strong content knowledge is paramount to receiving respect from students, which could lead to motivation for teachers to be competent in their area. Leung (2005) cautioned that each country’s culture influences learning and one cannot simply transplant practices from one culture to another without considering these differences.

**Considerations and Conclusions**

Cultural issues may have a big impact on learning in Singapore as compared to the United States that will not be addressed in this study (Leung, 2005). Tsui (2007) argued that differences could be due to social and environmental factors. Singapore generally has a more homogenous student population than does the United States, which makes transferability between Singapore and the United States complicated. Singapore students are considered to be highly motivated academically, and families in Singapore place a great emphasis on education (Ginsburg et al., 2005). Another variable to consider is teacher preparation. Teachers in Singapore have higher content knowledge than do teachers in the United States (Ginsburg et al., 2005; VanTassel-Baska et al., 2008). Further, Singapore is a very small country with a centralized education system, as compared with the large population and decentralized system in the United States.
However, given the growing influence of the NCTM Standards (2000) at the state level over the last several decades, and the adoption of more states of the Common Core State Standards for Mathematics in the United States, the trend is that U.S. education is becoming more centralized than it has been in the past. Variables such as culture and teacher preparation should be investigated in subsequent studies.

While there are major differences between the two countries, it’s likely that understanding the educational system in Singapore could help inform U.S. education, particularly in mathematics. Culture undoubtedly plays an important role, but individual strategies used in Singapore, and other high achieving nations, may be helpful for U.S. education. More studies should be conducted on the Singapore system with effectual aspects integrated into the U.S. system where relevant and possible.

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