

An Investigation of Mathematics Education in the United States
and Asian Countries:
Comparing and Contrasting Teaching Strategies and Practices

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Abstract

In the subject of mathematics, students in the United States score below their counterparts in other nations. Namely, students in Asian countries consistently outscore students in the United States. The Trends in International Mathematics and Science Study (TIMSS) provides scores for mathematics and science achievement for fourth and eighth grade students. Data for the TIMSS study has been collected in 1995, 1999, 2003, 2007, and 2011. Most recently, in 2011, data was collected for fourth grade students in 57 countries and other education systems and eighth grade students in 56 countries and other education systems. The scale average for the TIMSS study is set at 500. According to TIMSS (2011) fourth grade data, eight education systems had average scores higher than the United States. Among these eight education systems are: Singapore, Korea, Hong Kong, Chinese Taipei, and Japan. Similarly, eighth grade U.S. students scored lower than eleven education systems. Again, these systems include: Korea, Singapore, Chinese Taipei, Hong Kong, and Japan. Previous TIMSS data also supports the superior performance of Asian students.

Discussion

Though it is nearly impossible to note all of the reasons for Asian students' successes in mathematics, it is possible to explore, compare, and analyze the characteristics of mathematics teaching in both successful Asian countries and the United States. In addition, it may also be difficult to generalize the educational practices among the successful Asian countries. However, one can note specific differences between the education systems in the United States and Asian countries. Several commonalities exist among the teaching practices in Asian countries. One might

hypothesize that the differences between education systems in the United States and Asian countries, specifically regarding instructional techniques, may play a role in the mathematics success of students in Asian countries. The article, “Best Education in the World: Finland, South Korea Top Country Rankings, U.S. Rated Average” (*Huffington Post*, 2012), notes that the United States ranks 17th out of 40 education systems. Finland, South Korea, Hong Kong, Japan, and Singapore are all among the top ranking systems. This *Huffington Post* article says, “While Finland and South Korea differ greatly in methods of teaching and learning, they hold the top spots because of a shared social belief in the importance of education and its ‘underlying moral purpose’” (2012). While this cultural aspect may play a role in these countries’ successes, it is very evident that other factors are also involved.

Successful Asian Education Systems

According to the article, “The U.S. Must Start Learning from Asia” (Desai, 2010), Asia’s success is because of purposeful policies that are, and have been, in place. These policies work to benefit economic growth, and are truly investments in the future. Desai writes, “higher test scores in math and science are associated with higher growth rates that, in turn, lead to higher incomes” (2010). So, Asian school systems have created policies and practices that work to prepare learners to become meaningful contributors to economic growth. Desai has identified some ideas as to why Asian school systems seem to be more successful in teaching mathematics than those of the United States. To begin with, Asian education systems set very high curriculum standards for students. Students are expected to achieve the high standards that are in place. Teachers, in turn, must teach according to these intense curriculum standards.

The standards are also designed to “build on a student’s abilities step by step” (Desai, 2010). As students complete objectives, they build upon their skills to meet more complex ones. In Asian countries, schools also have the right and responsibility to create instructional plans that address the needs of all learners. It is important that the instruction and learning experiences are tailored to benefit different types and levels of learners. Next, education systems in Asian countries are comprised of high-quality teachers and are orchestrated by principals of great merit. Teachers are often selected from high-schools’ top graduates. Desai writes, “There are comprehensive systems for selecting, training, compensating and developing teachers and principals” (2010). Asian education systems make use of longer school years and days. They hold high expectations for all learners. Perhaps, most importantly, they place great emphasis on providing high-quality math and science educations. Each of the reasons that Desai has outlined may be indicators of Asian students’ success, and are items that should be considered as such.

Good Mathematics Teaching and Learning in Mainland China

China is an Asian country whose students have repeatedly out-performed their United States counterparts in mathematics. This is especially evident in the TIMSS data. In the article, “What Constitutes Good Mathematics Teaching in Mainland China: Perspectives from Nine Junior Middle School Teachers” (2012), Xinrong Yang makes note of important facets to good mathematics teaching and learning. Yang selected nine junior secondary school mathematics teachers to take part in this study. Teachers were selected to reflect a range of schools in Mainland China. In summary, the study identified seven specific qualities of good mathematics lessons: connecting teaching

content to real life, creating favorable teaching atmosphere and cultivating students' interests, encouraging students' participation, respecting students' differences, emphasizing the essence of mathematics knowledge, stressing the integration of knowledge, and developing students' mathematics thinking (Yang, 2012). Each of these qualities likely play a role in the mathematics successes of students in China.

Unanimously, the teacher subjects in Yang's study felt that good mathematics lessons must be connected to real life situations. Therefore, it is necessary that students have the opportunities to identify the importance and relevance of mathematics in their daily lives. Teachers must work to connect the concepts to students' experiences and interests. When learners can note how and why a concept is important to their lives, they will more likely be engaged in learning about it. In addition to this, six of the nine teachers noted that students can succeed in learning mathematics in appealing atmospheres. The classroom climate must be cooperative. The teacher should work to create a classroom where students are aware of expectations and have opportunities to learn in a positive environment. Teachers must truly know their students in order to succeed in teaching them. They must be conscious of their interests and specific abilities in and out of the classroom. They must know how to create lessons that "inspire and cultivate their learning interests" (Yang, 2012, p. 85). Lessons must be created to suit both different learning styles and skill levels. Next, all of the interviewees noted that students' active participation is vital for successful teaching and learning of mathematics. This means that students must have opportunities to explore and problem solve. They must be able to "discuss their thoughts, to look for problem solving solutions, or to discover mathematical rules

through their own explorations” (Yang, 2012, p. 85). Teachers should not tell just students what they need to learn and how they must learn it, as students all have unique ways of thinking and learning. Students should be able to actively make mathematics discoveries on their own as well as through interaction with their peers. Along these same lines, six of the nine teachers who participated in this study placed importance on being respectful of students’ individual qualities. Students enter the classroom with unique backgrounds, experiences, and abilities. Yang (2012) writes, “The six teachers remarked that for good mathematics teaching, a teacher should respect and pay attention to these differences” (p. 86) In addition to this, quality mathematics instruction should help students to “think mathematically” (Yang, 2012, p. 92). Yang also notes that, “when a teacher plans a good mathematics lesson, he should not only focus on the content of one individual lesson but take into account what the students learned before or will learn in future lessons connected to this topic” (2012, p. 88). These teachers therefore regard scaffolding as an important facet of good mathematics lessons.

Findings from the 1999 TIMSS Video Study

The TIMSS Video Study took place in alignment with the 1999 TIMSS. It provides visual representations and evidence of the mathematics and science teaching in seven countries. The study highlighted eighth grade teaching practices in Australia, the Czech Republic, Hong Kong SAR, the Netherlands, Switzerland, and the United States. The videos display actual lessons in actual classrooms in these countries. (These videos are available for viewing on the TIMSS Video Study webpage.) One can analyze, compare, and contrast the various teaching practices and classroom climates

while watching these videos. According to the TIMSS Video Study website, the study's purposes included investigating the teaching strategies that occur in classrooms in the United States and comparing those practices to those that occur in high-achieving countries. (TIMSS Video)

The article, "Mathematics Teaching in the United States Today (and Tomorrow): Results From the TIMSS 1999 Video Study" (Hiebert et al., 2005), uses the TIMSS Video Study data to compare mathematics teaching in the U.S. to the teaching in other countries. It uses the data to "describe a system of U.S. mathematics teaching in eighth grade characterized by frequent reviews of relatively unchallenging, procedurally oriented mathematics during lessons that are unnecessarily fragmented" (Hiebert et al., 2005, p. 116). Hiebert et al. (2005) also notes that teachers in the U.S. do not necessarily differentiate instruction based upon students' unique experiences and abilities. In addition, they do not always attend to the content that students have experienced in previous lessons. This contrasts the findings from Yang's (2012) study of teachers in Mainland China, which notes that an important facet of quality mathematics teaching is building off of students' prior learning experiences. This discrepancy denotes an important gap between teachers in the United States and Asian countries. In addition, the article notes significant difference in the amount of problems that were applications rather than simply exercises. According to Hiebert et al., "Exercises were defined as straightforward problems, usually presented with little context, for which a solution procedure apparently had been demonstrated" (2005, p. 117). Applications, on the other hand, required students to be aware of the reasoning behind the procedures used to solve problems. They were defined as, "problems that

appeared to require some adjustment to a known procedure, however slight, or some analysis of how to use the procedure” (Hiebert et al., 2005, p. 117). According to the TIMSS Video Study, 34% of problems on average per U.S. lesson were categorized as applications, while 74% of problems on average per lesson in Japan were categorized as applications. Along these same lines, 75% of private work time per lesson in the U.S. was utilized to repeat procedures while only 28% of time was utilized to repeat procedures in Japan. Interestingly, 81% of time in Hong Kong is utilized for repetition of procedures. This discrepancy is explained later in the article. Hiebert et al. note, “Even teachers in Hong Kong SAR, who appeared to focus on procedures when presenting problems, were found to examine conceptual underpinnings in an explicit way” (2005, p. 121). Rather than placing focus on conceptual understandings, teachers in the United States simply used procedural based problems as springboards for practicing the procedures themselves. “Hiebert et al. write, “Although the U.S. lessons momentarily appeared to show a balance among procedural and conceptual emphases, on the basis of the types of problems presented, follow-up indicators pointed to a uniquely heavy emphasis on procedures” (2005, p. 122). In addition to the gap in the use of procedural versus conceptual knowledge, it is also noted that classrooms in the United States place an emphasis on reviewing old material rather than building off of learned material. Using the TIMSS Video Study, Hiebert et al. note that 53% of time per lesson in the U.S. is spent reviewing, while 48% is spent on new content. In contrast, only 24% of time per lesson in Japan and Hong Kong is spent on reviewing. In both countries, 76% of time is devoted to learning and practicing new material. This 1999 TIMSS Video Study data analysis seems to align with Yang’s study on teacher’s ideas about good

mathematics teaching. The data appears to support the qualities of good mathematics instruction that the teacher subjects distinguished as important.

The scholarly article, "Are There National Patterns of Teaching? Evidence from the TIMSS 1999 Video Study" (Givvin et al., 2005), explores the idea that teachers in different countries "follow a cultural 'script'" (p. 314). Lessons from a specific country may have the same basic format or "script". In addition, it discusses the thought that teachers make unique uses of class time. Depending upon the culture and country, they may allot class time to different activities and experiences. Specific dimensions, including purpose, classroom interaction, and content activity, were noted in each of the countries that participated in the study. Furthermore, Givvin et al. (2005) analyzed the occurrences of these dimensions by coding the lessons. Givvin et al. write, "one way to illuminate these teaching patterns is to create a composite lesson pattern for each country" (p. 326). This was done "by graphing the number of lessons that were coded in a particular manner during every few seconds of lesson time" (p. 326). These "lesson signatures" note the specific characteristics of typical lessons in the countries that took part in the study. In comparing the United States with Asian countries, gaps exist between the amount of time spent on review versus practice of new material. The lesson signature of the United States notes that teachers spend large amounts of time reviewing previous material at the beginning of a class period, while the end of the class period is typically used to practice new material and concepts. In addition, lessons in classrooms in the United States involve mostly public interaction rather than private interaction. In contrast, the Hong Kong SAR lesson signature notes that teachers briefly review previous material. The middle part of the lessons tended to shift between

reviewing content, introducing the new content, and practicing or applying the knowledge gained in the lesson. Typically, the final portion of the lessons included some practice of the newly learned material. Interaction between the teacher and the students was a frequent occurrence in these lessons. Students were engaged in independent work for the majority of each lesson. The lessons culminated with concurrent problems, which were those that the class worked on or discussed in a whole-group setting. The Japanese lesson signature is relative to Hong Kong SAR's. Most Japanese lessons began with short reviews of the content learned in previous lessons. Given et al. note, "the introduction of new material was the most common purpose" (p. 329). The study also discusses the idea that Japanese lessons also made use of independent problems while students were either engaging in dialogue or working at their seats. According to this study, "Japanese lessons typically concluded with a discussion outside the context of a problem" (p. 332). Lessons in the United States and Japan seem to have completely different formats and facets, with Japan being the more successful system.

Mathematics Education in Germany, Japan, and the United States

The report, "Methods and Findings from an Exploratory Research Project on Eighth-Grade Mathematics Instruction in Germany, Japan, and the United States" (Stigler et al., 1999), also discusses the discrepancies between instruction in the three countries. This report aligns with the findings of Given et al. Stigler et al. outline four broad categories by which to label the differences: how lessons are structured and delivered, what kind of mathematics is presented in the lessons, what kind of mathematical thinking students participate in during the lessons, and how teacher view

the idea of “reform” (1999, p. VI). Stigler et al. also identify four key points from their findings. They note that mathematics lessons in the United States do not require students to engage in higher-level thinking as much as those in Japan and Germany. The article also states, “U.S. mathematics teachers’ typical goal is to teach students how to do something, while Japanese teachers’ goal is to help them understand mathematical concepts” (1999, p. VIII). It is also noted that Japanese mathematics lessons display the facets that have been identified as important by reforms in the U.S. However, lessons in the U.S. do not always display these features. Finally, the article states that U.S. Mathematics teachers are aware of the importance of reforming the educational practices, but do not always apply these practices in their classrooms. Several discrepancies exist between instruction in the United States and Japan. Again, Japan’s instructional norms may play key roles in their successes.

Specifically, the findings of Stigler et al. suggest that lessons in the United States have the purpose of teaching students to be able to solve problems. Students’ successes are measured depending upon their abilities to solve problems. These abilities may be based on students’ abilities to memorize procedures through repeated practice and application. However, the students may not truly understand the concept or procedures. Students may be able to carry out procedures, but may not know how or why they are successful at solving problems or acquiring solutions. Japanese lessons, however, have the goal of leading students to true comprehension and understanding. Students’ abilities to solve problems are, “merely the context in which understanding can best grow” (1999, p. VI). Along these same lines, the findings note that lessons in the United States typically contain two phases. First, the teacher demonstrates and

explains the concept. According to Stigler et al., this demonstration usually involves the instruction of some procedural knowledge. At the end of the lesson, students work on the concept independently by solving problems. At this time, the teacher assists students who are struggling with the concept. In contrast, lessons in Japan begin with some type of problem solving. Students all engage in solving a problem related to the concept being taught. They explore the problem and attempt to solve it using prior knowledge. Following this, students share the ideas that they have generated. The class works as a whole group to gain true comprehension of the concept. Japanese lessons allow the students to play key roles in their own learning. Next, the United States and Japan differ when discussing the type of content that is presented in the lessons. Stigler et al. write, “the average eighth-grade U.S. lesson in the video sample deals with mathematics at the seventh-grade level by international standards, whereas in Japan the average level is ninth-grade” (1999, p. VI). In addition to this, the instruction of concepts differs between Japan and the United States. According to the video study, three-fourths of the Japanese teachers developed concepts over the course of the lesson. These teachers lead the students to understand the concept, rather than just stating a formula or a process of steps. The students engaged in learning experiences that allowed them to learn through discovery. In contrast, one-fifth of the United States’ teachers taught like this. Students in the United States also spent significantly larger amounts of time practicing procedures than those in Japan. According to the Stigler et al. data, 90% of lesson time in the U.S. is spent practicing procedures, while only 41% of lesson time is spent on this in Japan (p. VII). This

finding seems to relate to the idea that teachers in the U.S. often teach procedures rather than leading students to true understanding through exploration and application.

Mathematics Teaching and Learning in Singapore

The article, “What the United States Can Learn From Singapore’s World-Class Mathematics System (and what Singapore can learn from the United States) (Ginsburg et al., 2005), provides readers with a cohesive comparison of the qualities that separate the two education systems. Singapore, a southeast Asian city-state, has continuously surpassed the United States in mathematics achievement. Singapore’s mathematics system greatly differs from that of the United States. To begin with, Singapore utilizes an organized, uniform mathematics framework that lays the ground for all teaching and learning. The framework revolves around the main idea of problem solving. Attitudes, skills, concepts, processes, and metacognition all play a role in the problem solving-based framework. All of these facets work together to create a system that is balanced between students’ abilities to use mathematical processes and their abilities to participate in deep thinking processes. Singapore makes use of the Asian practice of “spiraling concepts”. Students learn concepts that are grade-level appropriate. As they move up in the school system, they continue to learn about these concepts at more advanced and complicated levels. Students are held to a high standard, as they are expected to master concept specific skills before moving on to new ones. In contrast, the United States makes use of the National Council of Teachers of Mathematics (NCTM) framework. According to Ginsburg et al., “The NCTM framework, while emphasizing higher order, 21st century skills in a visionary way, lacks the logical mathematical structure of Singapore’s framework” (p. xi). According to Ginsburg et al.,

California, North Carolina, and Texas have adopted state-based frameworks that are similar to Singapore's. These three states have also been notably successful in mathematics. One may conjecture that a strong framework leads to higher performance and overall success. The United States lacks a strong, uniform framework, and this may be considered a deficit. An important quality of Singapore's education system is the fact that they provide students who may have difficulties in mathematics with an alternate framework that better suits their abilities and skills. This alternate framework allows for a slower pace with increased repetition. In addition, those who are having difficulties are provided with extra assistance from well-educated professionals. This characteristic of Singapore's education system ensures that all learners are provided with quality educations. The United States often places students who are having difficulties in slower paced classes. However, these slower paced classes do not ensure that students learn all of the mathematics topics that appear in the standards. This important distinction likely plays a role in the achievement gap that exists between the United States and Singapore.

Textbooks are also a category of discrepancy between Singapore and the United States. Ginsburg et al. note, "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" (2005, p. xxi). The accompanying illustrations of textbooks used in Singapore assist students who are visual learners. They represent multi-step problems and help learners to see how to solve such problems. As other data has shown, textbooks used in the United States typically only involve definitions and

procedural information. They simply aid in students' abilities to carry out mathematical processes rather than leading them to deep comprehension. Oftentimes, their illustrations include real-world examples, but do not necessarily show students how or why mathematics knowledge is vital in solving real-world problems. As mentioned before, Singapore's framework does not allot time for repeating information. As a result, their textbooks do not include information that students' should have learned in a previous grade. Textbooks used in the United States frequently include concepts that should have already been mastered. Rather than mastering skills and moving on to more advanced ones, students in the United States review and repeat concepts.

The Practice of Lesson Study

Educators are ultimately at the helm of education systems and their specific successes or failures. Administrators and teachers are responsible for carrying out lessons, implementing standards, and providing learners with quality educations. One of the most unique facets of the Asian education system involves teachers and administrators collaborating to provide students with meaningful learning experiences through "lesson studies". Japan is specifically noted as successfully utilizing lesson studies. In the article, "Overview of Lesson Study in Japan", Makoto Yoshida (n.d.) outlines the qualities of these unique experiences. Yoshida defines a lesson study as, "a process Japanese teachers engage in to continually improve the quality of the experiences they provide for their students" ("What Is Lesson Study?" section). Lesson studies can be categorized as professional development for Japanese teachers, and are completed for all realms of the curriculum. Unlike typical professional developments, lesson studies revolve around the students (Teachers College Columbia

University). Yoshida's article states that the majority of elementary and middle schools in Japan make use of lesson studies, however, lesson studies are uncommon at the high school level. According to Francis R. Curcio, many different types of lesson studies exist, but commonalities are evident (*A User's Guide to: Japanese Lesson Study: Ideas for Improving Mathematics Teaching*, 2002). These commonalities include collaborative planning, teaching and observing, analytic reflection, and ongoing revision (2002, p. 1).

When educators participate in a lesson study, they begin by noting a learning goal that needs specific attention. Teachers consider their students' abilities, successes, and achievements and compare these to the standards and goals that they want the students to meet. They consider the ways in which they can utilize students' abilities, skills, and knowledge to help them succeed. An example of a goal statement may be, "Developing well-thought-out mathematics lessons that provide students a feeling of satisfaction and enjoyment of mathematical activities while fostering their ability to have good foresight and logical thinking" (Yoshida, n.d., "Examples of Lesson Study Goals" section). Goals may also contain "sub-goals" that are placed in a timeline to be completed on a year by year basis until the goal in its entirety is obtained. After pinpointing a specific goal, educators then work cooperatively to create lesson plans and learning experiences that are aligned with this goal. In most cases, one teacher from the group that created the lesson plan teaches the lesson as others observe. Observers may include fellow grade level teachers, other teachers in the building or district, and administrators. This lesson is taught in an actual classroom in front of actual students. The observing teachers and other education professionals can make

note of the teacher's instructional strategies and students' responses to the lesson material. By doing this, they are able to identify successes, failures, and items for improvement. They may also examine student work and other assessments to judge the quality of instruction. Following the lesson, the observers and teacher gather to discuss, reflect upon, and revise the lesson as needed. They provide constructive feedback that is considered when altering the lesson plan. They offer suggestions for altering the lesson plan to better suit the goal. After the lesson has been revised, another teacher may teach the lesson while others observe. The teachers work together to create a report describing their findings and observations. Yoshida notes that specific, allotted times for staff meetings exist so that teachers are able to collaborate and discuss with one another. Lesson studies can be time consuming and require a lot of planning and effort. However, they are also extremely beneficial in obtaining education-based goals. In addition to working towards student achievement, lesson studies also aid in creating strong relationships among teachers and school administrators (Teaching Today). Lesson studies have been successful in Japan, and have begun to be used in the United States.

Dr. Catherine Lewis is a national expert on lesson studies, and is a scholar at Mills College in Oakland, California. Dr. Lewis has researched the practice of lesson studies and has played a key role in their implementation the classrooms in the United States. In an interview with Dr. Lewis, Anthony Cody of *Education Week Teacher* explores the use of lesson studies in the United States. According to the interview, lesson studies have been apparent in the United States for over a decade. They are mostly teacher-led, though they have been receiving some support from outside

organizations. Lewis notes, “Annual conference research lessons are held in several regions of the United States, including Chicago, New York, and several places in California” (Cody, 2011). Lewis is optimistic that lesson studies will become increasingly evident in the United States, and will be used as tools for reforming the education system. Lewis says, “With experiences lesson study groups now working across the United States, we could do this here” (Cody, 2011). She also notes, “We could recognize that we learn to teach better through cycles of planning and doing instruction, analyzing students’ responses to our instruction, and honing our instruction” (Cody, 2011). As students in the United States are consistently struggling with mathematics, something must be done. Lesson studies could very well become key parts of the United States’ education system, and could be utilized to create more effective mathematics lessons and learning experiences.

Conclusions

Quality teaching and learning are both vital for mathematics successes in the United States. Students need to be able to understand and apply mathematical practices. To do this, they must gain deep understandings of mathematics concepts. The United States has the opportunity to adopt some of the practices, standards, and strategies that have led to successes in Asian countries. With the adoption of the Common Core State Standards (CCSS), it seems that the United States has begun to do this. The “Introduction” section of the Mathematics Common Core State Standards document notes, “The composite standards [of Hong Kong, Korea, and Singapore] have a number of features that can inform an international benchmarking process for the development of K-6 mathematics standards in the U.S.” (p. 3). The Common Core

State Standards have been created to provide educators with clear expectations of what students need to learn. Like the standards in Asian countries, they integrate real-world, meaningful connections. They are designed to develop solid foundations in mathematical procedures so that learners will be able to apply their knowledge in meaningful ways. The standards build upon each other, and they are clear and concise. Students have opportunities to learn and understand mathematics concepts so that they may build off of their understandings in higher grade levels. In Kindergarten, students are expected to master number sense. They must be able to take numbers apart, put them back together, and realize that relationships exist among numbers. Students are expected to master basic facts about addition, subtraction, multiplication, division, fractions, and decimals in grades K-5. Students who have deep understandings of these topics will have the abilities to succeed in middle and high school mathematics classes. Teachers are provided with the necessary support needed for teaching students about difficult topics like fractions, geometry, and negative numbers. The CCSS set expectations for students that involve deep understanding. They expect all learners to have the abilities and knowledge needed to apply mathematics in non-procedural ways. (Common Core State Standards for Mathematics)

Perhaps the integration of the Common Core State Standards will lead to mathematics successes in the United States. This hypothesis will likely be accepted or disproved through the analysis of test scores and future TIMSS studies. It is clear that these standards do heighten the expectations of both teachers and learners while placing a definite focus on application and synthesis. They set the goal of leading learners to true understanding. Teachers, however, are ultimately responsible for

upholding these expectations and providing students with learning experiences that support them. Teachers must remain knowledgeable of best practices through research and continual education. They must lead students to reach deep levels of comprehension through engaging lessons and activities. It is vital that educators work to support students in making connections between mathematics and everyday life. One can remain hopeful that schools, administrators, and educators will collaborate and continue to reform standards and educational practices in order to improve mathematics teaching and learning.

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