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A Comparative Analysis of Top Performing Countries in Eighth Grade Mathematics as Measured by 2011 Trends in International Mathematics and Science Study

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A COMPARATIVE ANALYSIS OF TOP PERFORMING COUNTRIES IN EIGHTH GRADE MATHEMATICS AS MEASURED BY 2011 TRENDS IN INTERNATIONAL MATHEMATICS AND SCIENCE STUDY

by

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ABSTRACT

The focus of this research was to shed light on factors contributing to global international rankings in mathematics released by the 2011 administration of the Trends in International Mathematics and Science Study. This study focused on factors contributing to the global ranking of international scores in mathematics.

Although students in the United States performed below students in the other sample countries (Singapore, Japan, and the Republic of Korea), American students scored within one standard deviation of the top performer, the Republic of Korea. The study also revealed that although other countries had their brightest and most advantaged students participate in the assessment, participating students in the United States were disproportionately disadvantaged to the proportion of United States' citizens. Another contributing factor of student success revealed in this study was the size and form of government and financing of the participating countries. While Singapore, the Republic of Korea, and Japan have education systems governed and financed by national governments, the United States education system is primarily governed and financed by 50 state governments.

To my sons, Conner, Cameron, and Clay

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LIST OF ACRONYMS

CIEB	Center of International Education Benchmarking
ESEA	Elementary and Secondary Education Act
IAEEA	International Association for the Evaluation of Educational Achievement
IEA	International Education Agency
NCEE	National Center for Education and the Economy
NCLB	No Child Left Behind
NCTM	National Council of Teachers of Mathematics
RTTP	Race to the Top
STEM	Science Technology Engineering and Mathematics
TIMSS	Trends in Mathematics and Science Study

CHAPTER 1
THE PROBLEM AND ITS CLARIFYING COMPONENTS

Introduction

One tool used by the international community to evaluate student success in mathematics and science is the Trends in International Mathematics and Science Study, (TIMSS) developed by the International Association for the Evaluation of Educational Achievement. This assessment has measured international mathematics and science scores for students in Grades 4 and 8 every four years and also has been used to gather demographic data from students, teachers, administrators, and national research coordinators for each participating country. A total of 63 countries have participated in various administrations. Participation in every administration has not, however, been required. A list of all of the participating countries can be found in Appendix A. Of the 63 countries participating, the United States was the only country participating in every sub-area in each of the five administrations since 1995. The most current TIMSS data, 2011, were released in December, 2012.

The 2011 TIMSS data included student socioeconomic demographics as well as information on student home life, school climate, and self-perception. Questionnaires completed by teachers, yielded information such as: teacher preparation, professional development, and experience teaching. School questionnaires completed by principals included information on: student demographic characteristics, the availability of resources, types of programs, and environments for learning in their schools. A national

research coordinator for each participating country also completed a questionnaire based on the organization and content of the mathematics curriculum, (TIMSS, 2011a).

Statement of the Problem

To date there has been little to no research concerning factors contributing to student achievement in the United States scoring significantly below those in Asian countries as measured by the Trends in International Mathematics and Science Study (TIMSS). Eighth-grade students in the United States ranked 12th among their peers in Mathematics globally, (TIMSS, 2011). Such factors contributing to student achievement include: (a) the similarities if any, existing in student demographic information in the sample countries with regard to gender, socioeconomic status, student age, the total population of students in school, and total population of students participating in the assessment; (b) the similarities if any, existing in the mathematics curriculum in the sample countries ; the similarities if any, existing in the mathematics curriculum in the sample countries ; (c) the similarities if any, existing in the authority, governance, and finance of the education systems in the sample countries ; and (d) the similarities if any, in the required credentials for educators.

Purpose of the Study

The purpose of this study was to analyze factors contributing to the ranking of top performing countries as measured by the eighth-grade mathematics scores of the Trends

in International Mathematics and Science Study examination. Such factors contributing to student achievement include: (a) the similarities if any, existing in student demographic information in the sample countries with regard to gender, socioeconomic status, student age, the total population of students in school, and total population of students participating in the assessment; (b) the similarities if any, in required credentials for educators in the sample countries ; (c) the similarities if any, existing in the mathematics curriculum in the sample countries ; the similarities if any, existing in the mathematics curriculum in the sample countries ; (d) the similarities if any, existing in the authority, governance, and finance of the education systems in the sample countries .

In this study, students in the United States were compared to peers in other top performing countries; (Singapore, The Republic of Korea, and Japan). Factors were analyzed relating to school demographics, curriculum, teacher preparation, policy, and costs in global education systems. The information gained in this study was intended to be used to influence decision making in the United States education system for the purpose of increasing student achievement in mathematics.

Significance of the Study

The significance of this study rested in the provision of additional insight for the educational community on the contributing factors of Asian countries and their high performance on the 2011 administration of the TIMSS in mathematics over all other countries. The TIMSS database included the results of questionnaires completed by participating schools, teachers, principals, and parents focusing on data such as student

demographics, curriculum, and teacher preparation. It is important for the educational community to analyze this data to deepen understanding on factors contributing to scoring well above international averages. In his 2011 State of the Union Address, President Obama spoke to the need to better prepare the nation's students in the areas of mathematics and science in order to be competitive in a global economic and jobs market:

> The quality of our math and science education lags behind many other nations. America has fallen to ninth in the proportion of young people with a college degree. And so the question is whether all of us--as citizens, and as parents--are willing to do what's necessary to give every child a chance to succeed. (Obama, State of the Union, 2011, para. 35).

Definition of Terms

The following terms are defined, for the purposes of this study, as follows:

Constructivism. Refers to the paradigm of how knowledge is gained by the synthesis of new information and prior experiences

Curriculum. Includes the subject specific standards covered in public school prior to the administration of the TIMSS.

Educational Policy. Laws governing the education system

Outcome Based Education. Refers to measuring student performance by a common set of standards

Standards Based Education. Refers to an objective matrix by which student performance is measured

School Demographic Information. Refers to socioeconomic, language proficiency, home environment, school climate, parental support, and special needs information of students enrolled in public school

Teacher Preparation. Refers to information about university teacher preparation programs, certification requirements, recertification requirements, and continuing professional development.

21st Century Learning. Refers to the skills needed by current students to adapt to global learning and working environments.

Theoretical Framework

The theoretical framework of this paper was focused on the cognition component of mathematics assessed by the TIMSS. In exploring the theoretical framework, the researcher presented information on the theory of constructivism in learning centered on linking new information with prior knowledge. This theory stems from post-modern thought and presumes that through active engagement, the learner will make a deeper connection and have a more complete understanding of the subject matter. The theory of constructivism posits three main ideas: knowledge is constructed by individuals based on experience, knowledge does not exist outside the mind, and truth is not absolute (Yilmaz 2008). Constructivist theory supports the idea that perception is reality. An example of that idea is that history is written by the victorious. When individuals or individuals

within groups decide what is true, knowledge for that group is formed. Two groups in opposition will have different versions of the same knowledge, and both versions are true.

The construct of the TIMSS has been focused on both the content and cognitive domains in mathematics. This practice falls in line with the theory of constructivism in education, and more specifically, Dewey's theory of pragmatism in learning. Dewey (1966), with Meade, conceived a point that learning occurs at the crossroads of a problem and solution. The learner must find multiple ways to solve the problem and choose the method of best fit, (Sutinen, 2007).

The works of Dewey in the field of educational psychology have earned him the unofficial title of "Father of Constructivist Learning" (Dewey, 1955, 1960, 1966) in the American field of education. His work, along with that of Meade, laid the groundwork for what is arguably the most researched method of teaching in post-modern education. Beyond this, there have been many variations of constructivist thinking arrived at by notable researchers. This includes the radical constructivism of Vygotsky and the social constructivism of Piaget (1980).

Dewey's definition of the construct of thinking is that it is an idea which arises in a situation where something happens that, from the perspective of the thinker, is an incomplete event (Dewey 1955, p. 171). According to Dewey, thinking is a process of inquiry. It involves looking into things and investigation (Dewey 1955, pp. 176-177). To explain the steps of forming thoughts, Dewey outlined a five step process he called the Method of Intelligent Learning (Dewey 1955, pp. 180-181):

1. The Problem Emerges – a situation is not in the individual's control and there is something unclear or confusing
2. Interpretation of the Problem – The individual assesses the situation with the resources available (in education, this is where teachers begin aide the thinking process)
3. Problem Analysis – the individual tries to systematically understand elements of the problem
4. Construction of Hypothesis – With the help of instructors, the individual uses the facts of the problem and the resources available to test for solutions
5. Solution to the Problem – new knowledge is formed or "incursion occurs which is the added information to previously learned knowledge is added

As a philosopher Dewey was not concerned with whether ideas were formed as an individual (radical) or as a group (social), only in the construct of the formation of ideas and thinking in itself. Dewey defined "ideas" as qualities that can be separated, joined, or further manipulated in such a way that meaning is perceived. Learning takes place when thinking is a cognizant and intentional process. Dewey did not, however, account for learning that takes place by happenstance or results from the unintended consequences of failed experiments.

Meade actually began his research before Dewey but was brought into the mainstream by him. Though he explained the construct of thinking in much the same way as Dewey, he posited a three-step process of thinking in contrast to Dewey's five steps: (a) the problem, (b) the hypothesis, and (c) experiment and solution.

Sutinen (2007) wrote that according to Meade, humans are looking for homeostasis in a world that is constantly presenting new problems between individuals' environments and their experiences. Meade posited that the act of thinking was creative through adaptation. When individuals are able to creatively adapt to change they can create reproducible results to new problems. The ability to do so, according to Meade, was evolution.

Thus, the theoretical framework for the study was focused on the inquiry-based teaching methodology used to facilitate education through the process of increasing student metacognition. The theoretical framework also included information on the contextual frameworks of both the TIMSS Mathematics assessment and background questionnaires

Research Questions

1. What similarities, if any, existed in the student demographic information in the sample with regard to socioeconomic status, student age, gender, total population of students in school, and total population of students tested?
2. What similarities, if any, existed in the required credentials for educators in the sample in regard to degrees earned, certification requirements, professional development, and collaboration with peers?
3. What similarities, if any, existed in mathematics curriculum in the sample with regard to the order of instruction, educational pedagogy, and delivery models?

4. What similarities, if any, existed in the policies, governance, and finance of the education systems in the sample with regard to the levels of government making educational policy, landmark legislation in education, the structure of educational systems, the use of national curriculum standards, the use of national assessments, and information pertaining to the funding of public education systems?

Limitations

Many variables outside the scope of the research may have had significant impact on factors contributing to student test scores. One such factor is the cultural value of education, mathematics education in particular, placed on it by society. Some countries may have over- or underestimated the value or emphasis placed on the importance of student achievement in mathematics. Another factor is that some countries may have over - or underestimated confidence levels in teacher preparedness. Some countries may have over - or underestimated student perceptions of their ability or perceived value in mathematics. Another factor contributing to student test scores was the perceived cost/benefit due to direct payment of tuition by parents rather than indirect payment through local, state, or national taxes.

Delimitations of the Study

In this study, mathematics scores of eighth-grade students, as measured by the 2011 administration of the TIMSS, were compared. A list of participating countries and

their average student achievement scores are shown in Appendix A. Of the G8 countries, Canada, France, and Germany did not report scores in the 2011 administration of the TIMSS. Japan's scores were the highest with 64%. Russia was next with 56%. The United Kingdom and The United States tied for third place with 48% (Miller & Warren, 2009). Benchmark testing for the 2011 administration of the TIMSS in mathematics took place in Canada, the United States, and the United Arab Emirates.

Assumptions

This study included the following assumptions:

1. The selected scores were reported accurately by participating countries.
2. Testing conditions and parameters were consistent throughout testing locations
3. The test was administered to all eighth grade students in the public education system.

Methodology

Population and Sample

The population of the study consisted of eighth-grade students assessed in the 2011 administration of the TIMMS in the subject area of mathematics in 63 countries. The sample was comprised of those students from the countries of Singapore, the Republic of Korea, Japan, and The United States. These countries were chosen by

creating quartiles, in which The Republic of Korea was at the top, the United States was at the bottom, and Singapore and Japan were evenly spaced in between.

Research Design

The research design of this qualitative study was phenomenological in nature and required a content analysis of public archival data. The purpose of phenomenological study is to illuminate trends in archival data. The researcher chose this form of quantitative study to shed light on trends in student achievement in mathematics content and cognition in eighth-grade students in Singapore, the Republic of Korea, Japan, and the United States.

Data Collection and Analysis

Data collection was based on archival records and documents retrieved from the National Center for Education and the Economy (NCEE) and the Center on International Education Benchmarking (CIEB). Other archival data were analyzed from the Trends in International Mathematics and Science Study (TIMSS).

Organization of the Study

This study has been organized to include five chapters. Chapter 1 has presented the background of the study, statement of the problem, purpose of the study, significance of the study, definition of terms, conceptual framework, research questions, limitations, delimitations, and the assumptions of the study. Chapter 2 contains a review of literature which was focused on the constructivist theory of learning in education. Chapter 3

explains the methodology used to conduct the study. It also included a discussion of the selection of participants in the study, instrumentation, and data collection and analysis procedures. Chapter 4 presents the findings of the research including demographic information organized around the research questions which guided the study. Chapter 5, the concluding chapter of the study, contains a summary of the entire study, discussion and implications of the findings, recommendations for further research, and conclusions.

CHAPTER 2
REVIEW OF LITERATURE

Beyond Dewey in Constructivism

One educational pedagogy which has been in popular practice in mathematics education since the 1990s in the United States is the theoretical framework of constructivist learning. This theoretical framework stems from the works of Dewey with the theory of progressivism in the 1920s and 1930s. Two major constructs of constructivist learning have been posited by educational researchers. Radical constructivism is a theory supported by von Glasersfeld (1989, 1990, and 1995) and Hardy and Taylor (1997). The concept of radical constructivism is that mathematical understanding is created by a student's own experiences in nature. Therefore, each student has his/her own concept of reality. Social constructivism, which has been supported by The National Council of Teachers of Mathematics [NCTM] (Stiff, 2013), argues that one does not derive an individual sense of reality on one's own by interacting with nature alone. Because students interact with not only nature but with their peers, parents, and teachers, they develop a shared understanding of mathematical concepts. The use of social constructivism itself is not a set of pedagogical practices but a set of reflective practices by the teacher based on students' prior knowledge. Social constructivism is also not a method of discovery learning where students "happen upon" mathematical concepts by accident but a method of reflection and manipulation on the part of the teacher to access student prior knowledge and increase content knowledge,

thereby increasing mathematical understanding of reality. The social interaction of changing the understanding of reality is the process of learning, (Henessey et al., 2012).

Embedded within the two major constructs of the theory of constructivism are three main dimensions of constructivism as outlined by Phillips (1995) and clarified by Perkins in 1999. The three main dimensions of constructivist learning are: (a) individual psychology vs. public discipline, (b) active learning: humans the creators vs. nature the instructor or (c) social learning, and construction of knowledge as an active process or creative learning.

Because the theory of constructivism is not just one idea, the work done on the theory by many educational researchers can be placed along a constructivism continuum. For example, the idea that students learn by being actively engaged in discussion, debate, and analysis has been supported by the worked of Piaget, (1980) in that knowledge does not result from mere observations without a structuring activity. Though the predisposition of intelligence is hereditary, actual learning is a constructivist process. The idea that students learn by being socially engaged with their peers and instructors when they are able to link prior knowledge with new knowledge was supported by Locke, (1947). The idea that students learn by creating was supported by Dewey, (1960) in that learning is not passive. Rather, it is participatory inside the natural and social scene, and true knowledge resides in the consequence of directed action. Perkins, (1999) cited the following football analogy to explain the process of creative learning: one can have knowledge about the game of football by being an outside spectator, but actual learning and deep understanding is attained by becoming actively involved in the process.

The practice of actively, socially, and creatively learning fosters the idea of differentiated instruction by allowing students to become involved in the process of learning. They are no longer passive spectators but participants in their own education. Perkins, (1999) further explained that social and creative learning automatically accompany active learning, but active learning does not necessarily include social or creative learning.

According to Perkins (1999), the use of constructivist methods of learning are effective in teaching different types of knowledge. Inert knowledge is that which sits in the back of one's mind until recall is needed but is not readily used. An example of inert knowledge is passive vocabulary. The student knows what the word means but does not use the word on a regular basis. One way to use a constructivist method in teaching knowledge that may become inert is to have students connect the new knowledge with current situations in society, their own lives, or other pieces of literature.

Ritual knowledge is that which includes names, dates, figures, or rules that were traditionally memorized in the traditional sense of learning. A constructivist method of teaching ritual knowledge is to have students present the rationale behind it, e.g., describe the global economic climate that led Columbus to sail the ocean blue in 1492 (Perkins, 1999).

Conceptually difficult knowledge is that which is in conflict with a student's perception of common sense. One example is the idea that big, heavy objects fall faster than small, light objects. A constructivist method to teach the principle that objects fall at the same speed regardless of size or weight is creative learning. Using an inquiry-based

approach, students can easily and quickly participate in an experiment to demonstrate the principle in action (Perkins, 1999).

Foreign knowledge is that which competes or contradicts students' prospection or perceptions. Knowledge or beliefs in religion, culture, and history is often one-sided, written by the winner, the richest, or most powerful. A constructivist approach to teaching foreign knowledge is to acknowledge multiple, valid perspectives through the use of debate, discussion, or role play (Perkins, 1999).

As a practical concern, there are some negative aspects to constructivist learning. Learning constructively is highly effective but requires a degree of cognition and aptitude with which not all students are equipped. Students with some disabilities, like cognitive processing disorders, may have to place so much focus on the act of live participation that they miss the objective of the lesson itself. Constructivist learning is not the best fit for all lessons. For example, creative learning focuses on the rediscovery of rules or principles. In complex lessons some things do not need to be rediscovered every time they are applied to a portion of a lesson. Sometimes it would be more effective to accept that certain rules or principles are true in order to get to the more important goal or objective. Finally, due to the everyday demands on time in academic life in the public school system, constructivist methods of learning are not always practical for every lesson every day.

Because the business of education is to impart knowledge to individual students in need of individualized instruction, one best fit approach to teaching does not exist. The constructivist theory of learning is no different, even with its continuum of styles and

methods. In order to be most effective, teachers use constructivist methods on more, but not all, difficult concepts.

Radical and Social Constructivism

Radical Constructivism

Radical constructivism has to do with the construct that knowledge is not obtained through telling on the part of the instructor nor listening on the part of the learner. It has to do with learners transcending their preconceived conceptual structures by reorganizing their current thoughts into new thoughts. This is managed by an instructor introducing problematic scenarios in which the current thinking of the student will be insufficient in solving. In order to solve the problem, students must reorganize their thoughts based on past experiences. In doing so, new knowledge is acquired. The instructor's position is to facilitate students' being able to form new knowledge on their own, not to actually form the new knowledge for the student by simply telling new information and asking the student to accept it without question (Joldersma 2011).

The most prominent advocates of radical constructivism in the field of education were Piaget (1980) and von Glasersfeld (1995). Von Glasersfeld (1995)posited a five-step approach to incorporating radical constructivism into instruction:

1. Instructors should create opportunities for students to trigger their own thinking.

2. Instructors must not only know their content but how the curriculum connects to real-world situations that are relatable to students' lives.
3. Instructors must realize that mistakes are not wrong, per se, but provide an opportunity to see how students arrive at a solution and serve as a guide in the process of finding the right answer.
4. Instructors must use meaningful content vocabulary, not necessarily technical terms, that will make sense to their particular student audience.
5. Re-conceptualization requires reflection which is most effectively accomplished through meaningful conversation between the instructor and the student.

Von Glasersfeld addressed (1995) of the concept of "fit." When students' experiences "fit" with their conception of "how things are," what students know is validated. It is when experiences do not fit that students must form new knowledge (Joldersma 2011).

In conclusion, radical constructivism was accurately summarized by Wheatley (1991). Wheatley believed that knowledge was not passively received but was actively built up by the learner. Knowledge was not something floating in space waiting to be captured but something people "do" together. It is an interplay between the instructor and student. It is always contextual and is never separated from the learner.

Social Constructivism

The most prominent theorist involved in social constructivism in the field of education, according to Fox (2001), was Vygotsky. His work on the construct of social learning included the strategies of learning within the zone of proximal development (ZPD), scaffolding, and cooperative learning. Whereas Piaget and others would argue that learning most effectively occurs within the learners' individual mind and experiences, Vygotsky and other social constructivists would say learning most effectively occurs within the conversations of social learning groups (Fox 2001).

The epistemology of social constructivism focuses on the construct that learning is a group process. Learners are part of a community, and learning does not take place in isolation. A similarity of social and radical constructivism is that learning is situation-specific and bound by context. Where radical constructivists would argue that learning is relative only to an individual, the radical constructivist would argue that learning and knowledge are relevant to learning communities (Liu & Matthews, 2005).

Constructivism in Mathematics

A construct of mathematical pedagogy is that of persuasive pedagogy. This theory presented by Murphy, (2001) posited that there was no one best way to problem solve which involves the basic premise of constructivist thinking. This idea fosters the notion that students are not blank slates each year when they walk into new classrooms. They have preconceived notions of their own mathematical reality. The use of persuasive pedagogy allows the teacher to encourage students to problem solve in their own way

with the expectation that they will be able to communicate their thought processes. When students have misunderstandings in their mathematical thought processes, an opportunity is opened for dialogue between the students, teacher, and peers to engage in social constructivism to correct student mistakes. Mathematical learning does not derive from memorization of one problem-solving method but from a deeper understanding of how numbers work, the ability to use multiple forms of problem-solving, and the ability to communicate why a problem-solving method was chosen over another. This construct of mathematical learning, although not called persuasive constructivism, has been supported by the National Governors Association Center for Best Practices (NGACBP) and the Council of Chief State School Officers (CCSSO) in the development of Common Core State Standards as well as the NCTM.

History of Mathematics in Ancient Times

Some of the earliest recordings in human history have been of the practice of mathematics. Evidence of the earliest usage of mathematics has been discovered in Mesopotamia, Greece, and China. In these earliest recordings, mathematics was used primarily in practical matters such as agricultural practices, the passage of time, and in the collection of local taxes. In this section, the researcher has provided a brief history of mathematics in ancient Mesopotamia, Greece, and China.

Mesopotamia

According to Hodgkin (2005), the earliest discovered mathematic writing was from Mesopotamia, the area between Egypt and modern-day Iraq. Archeological discoveries of clay tablets depicting mathematical writing have been dated as far back as 3000 BCE. One artifact described by Hodgkin was a Sumerian tablet depicting a mathematical tally of different types of pigs. It is important to note that in this tablet written expression in numeric forms seemed to predate phonetic expression, as the description of the different types of pigs was in pictorially depicted (Hodgkin 2005). Other Sumerian tablets showed the culture practiced basic forms of mathematics. Archeological discoveries have shown that ancient Egyptians also practiced basic mathematics. However, artifacts were rare, because the Egyptians routinely used papyrus.

The Babylonian culture also used the written expression of Cuneiform but in the Akkadian language rather than Sumerian. In his book, Hodgkin (2005) described a Babylonian tablet dated around 1800 BCE depicting a word problem for finding the weight of a rock. The tablet had representations for fractions and an algebraic equation. Hodgkin noted the equation was not well written but showed that ancient cultures were thinking of mathematics in terms of abstracts. Ancient Babylonians also had a standard representation for numbers. Unlike the Greek, and Western European systems, which were based on the number 10, the Babylonian system was based on base 60. The system used numeric representations for numbers 1-59, with no expression for 0 (Hodgkin 2005).

Greece

The Western European and American system of mathematics originated in ancient Greece with works from Thales, Pythagoras, Plato, Euclid, and Aristotle, among others. The system of basic mathematics of the ancient Greeks was not that much different from that of the Ancient Sumerians, Babylonians, and Egyptians as far as procedures. The main difference with the ancient Greek system of mathematics was the advocacy of providing proof of an answer. The ancient Greeks also displayed a willingness for debate and argument over mathematical procedure (Hodgkin 2005).

The earliest Greek mathematicians were Thales and Pythagoras. Thales is the first credited mathematician credited to use deductive reasoning in geometry. He is also the first to have a mathematic discovery attributed to him. Pythagoras is said to have studied geometry from the Egyptians and Babylonians. The Pythagorean School holds that mathematics is the basis of the universe (Boyer 1991).

Although primarily concerning the idea of virtue, in his work *Meno*, Plato (Boyer 1991) stated there are two types of mathematics: practical mathematics used for accounts and measuring and a superior mathematics used for other purposes. This superior mathematics to which he referred was abstract mathematics which he also called real mathematics. In abstract mathematics, numbers no longer represent individual things but are independent as objects themselves.

One student of the Platonic Academy was Eudoxus. Eudoxus has been considered one of the greatest of the ancient Greek mathematicians. Eudoxus was credited with developing the idea that circles and squares with the same radii had the

same area, and that spheres and cubes with the same radii had the same volume. He also introduced the idea of working with lines and angles (Kline 1972).

Other famous mathematicians in ancient Greece were Euclid and Archimedes. According to Boyer (1991), Euclid took mathematic methods and organized them into standard procedures in his *Elements*. The intention of the books was to be an introductory textbook of mathematical topics such as number theory, algebra, and geometry (Boyer 1991). Boyer also addressed the work of Archimedes, crediting him as having completed the first works with calculus, establishing the calculation for pi, the spiral, and a system for expressing very large numbers (Boyer 1991).

China

The general agreement among scholars, (Kangshen, Crossley, & Lun 1999; Struik, 1948) is that the earliest writings of mathematics in China, much like Mesopotamia and Greece, had to do with the recording of the passages of time and as an aid in agriculture. The definitive source of mathematics, as a study in itself, is *The Nine Chapters of Mathematics and Art* (Kangshen et al., 1999). This textbook was written sometime prior to 221 B.C. but in that year the emperor, Shi Huangdi, had all books of knowledge burned. The original author is unknown. *The Nine Chapters* and some other books of knowledge were re-written from memory. It has been annotated many times and many different authors have added supplemental material. Other mathematical writings are difficult to place prior to 700 A.D.

The Nine Chapters of Mathematics consists of 246 problems and solutions and has been organized into nine categories. These categories are: rectangular fields, millet and rice, distribution by proportion, short width, construction consultation, fair levies, excess and debits, rectangular arrays, and right-angled triangles.

Although the basis of mathematics in ancient China developed independently from that of Middle Eastern or Western countries, the purpose of aiding agriculture was the same. One major difference in the development of mathematics between ancient China and other ancient countries is that in Greece, for example, there has been a strong emphasis on proofs first and then building algorithms to fit the proofs. In ancient China, according to Kangshen et al (1999), there has been very little emphasis on proofs. The emphasis in native Chinese mathematics has been to build algorithms that lead to correct answers.

Summary

The practices of mathematics developed due to practical needs, emerging over time as a study, in itself, independently throughout the ancient world. It is clear that over time different civilizations influenced one another in their development of mathematics in their interactions. Different civilizations may have used different methods and mathematical characters, but as early as the 1600s and as late as the 1800s with international trade and exploration, the study of mathematics was no longer thought of as belonging to one civilization or another but as belonging to the international community (Struik 1948).

History of Teacher Preparation

In ancient times the profession of teaching was almost entirely male. The idea of formal teacher preparation did not exist (Maurice, 2013). Teachers in ancient times were contracted independently as private tutors. These teachers were autonomous in practice and were only accountable to those who employed them. This accountability did not generally extend to pedagogy. Ancient Romans had a trade guild for teachers, but it functioned more as a social club than a professional organization. The general attitude of the purpose for education was that of "intellectual superiority, emotional restraint, and physical dominance" (Maurice, 2013, p. 214).

With the changes in national governments shifting from autocratic to democratic in the 1800s, the idea of the purpose of education went from being only attainable by the elite to being a right of everyman. With the rise of democratic nationalism came the desire for public education, and the attitude about the purpose of education shifted from being one of intellectual superiority to that of "emotionality, maternal love, and moral superiority" (Maurice, 2013, p. 214). Although still a male dominated profession, this shift was known as the feminization of education (Bansel 2009).

According to Coble, Edelfelt, & Kettlewell (2004), teacher preparation in Europe and the United States began in the 1830s with normal schools. It was largely influenced by teaching schools being established in France and Germany and by the educational philosophies of Pestalozzi and Froebel. Pestalozzi believed that education should be based on what students can hear, see, and touch in their immediate environment. Frobel, a student of Pestazolli, worked primarily on the education of early childhood. With the

efforts of Mann and others, the first public normal school in the United States was opened in Lexington, Massachusetts in 1839. Typically, student teachers studied the subjects they would eventually teach along with methodology and in-service teaching for up to one year (Coble et al., 2004).

The earliest normal schools offered programs lasting from a few weeks to one year, and students entering normal schools had usually just finished their own elementary schooling. The profession was largely practiced by men and served as a stepping stone into studying for the ministry. Women who joined the profession also did so as a bridge between their own education and marriage. It was not until 1894 that Massachusetts required high school graduation as an entrance requirement into normal schools (Coble et al., 2004).

Normal schools transitioned to teaching colleges in the second decade of the 20th century. At that time, secondary school teachers were trained at the university level. Elementary school teachers were prepared in normal schools and then teaching colleges. There has long been debate over what exactly should be taught in teacher preparation programs. The preparation of elementary teachers has focused more on the pedagogy of learning. In contrast, secondary teachers have focused more on the content of their respective disciplines. From the earliest days of the public education system and the preparation of teachers, there has been the support for the need of public education, but public support for the identification of teaching as a profession has not been as robust as that for other professions (Coble et al., 2004).

At the time of the present study, elementary and secondary teachers were being prepared in colleges and universities, and each state has had varying requirements for the preparation of educators. In general, there have been two ways to earn a professional teaching license in the United States. The first is a liberal arts based approach in which the focus of the preparation is on the philosophy and pedagogy of education. Under this constraint, students earn education degrees. Upon graduation, prospective teachers must pass a state professional educator examination and a subject-specific examination in order to earn a professional teaching certificate, (U. S. Department of Education [USDOE], 2013).

The second approach to earning a professional teaching certificate is to earn a bachelor's degree in a subject other than education and pass a subject-specific education examination. The student may then apply for a temporary teaching certificate. Upon the issuance of the temporary teaching certificate, the student must complete a rigorous set of professional development courses in educational philosophy and pedagogy. The student must pass the state professional educator's examination before being issued a professional service contract, (U. S. Department of Education [USDOE], 2013).

Professional educators must be recertified every five years. Each state has different requirements for recertification; but in general, requirements for recertification include participation in continuing professional development. Most state- and district-based professional development courses are offered at no charge. Many state and national education conferences can be paid for with the application and award of grants sponsored by professional organizations. Continuing education opportunities are

available for professional educators. The federal government offers subsidized or reimbursement for educators seeking advanced degrees in critical shortage areas such as mathematics, the sciences, English as a second language, and special education services (USDOE, 2013).

Contextual Framework of TIMSS Mathematics Assessment

The purpose of the TIMSS is to investigate how educational opportunities are provided to students and how students use those opportunities. The TIMSS is used to investigate education on three levels: the intended curriculum, the implemented curriculum, and the attained curriculum. The intended curriculum is defined as that which global societies want students to learn. The implemented curriculum is that which is actually taught, by whom, and how. The attained curriculum is that which was learned. The intended and implemented curriculum was measured by faculty and student questionnaires. The attained curriculum was measured by the assessment.

The contextual framework of the TIMSS Mathematics Assessment at the eighth grade level consisted of two major parts: content domains, and cognitive domains. Content domains and percentage of items were as follows: number sense, 30%, algebra, 30%, geometry, 20%, and data and chance, 20%. Concepts included in the assessment of number sense were as follows: whole numbers, fractions and decimals, integers, and ratio, proportions, and percent. Students at this level were expected to have computational fluency and be able to use these types of numbers to solve problems. Concepts included in the assessment of algebra were as follows: patterns, algebraic

expressions, and equations/formulas, and functions. Students at this level were expected to use and simplify algebraic expressions, solve linear equations, inequalities, pairs of simultaneous equations involving multiple variables, and use a range of functions. Students were also expected to solve real-world problems using algebraic models and explain relationships involving algebraic concepts. Concepts included in the assessment of geometry were as follows: geometric shapes, measurement, location and movement. Students at this level were expected to analyze the properties and characteristics of two and three dimensional shapes, use the Pythagorean theory to solve problems, use measurement tools accurately, estimate where appropriate, and select formulas for perimeter, area, and volume to solve problems. Students were expected to use coordinate representation to move between two and three dimensional spatial reasoning and use symmetry and transformation to analyze mathematic situations. Students were expected to describe, visualize, and construct angles, lines, and polygons as well as construct and deconstruct compound shapes. Students were also expected to interpret side or top views of shapes. Students were expected to use the Cartesian plane to locate points and lines. Students were also expected to interpret symmetry, rotations, translations, and reflections in mathematical figures. Concepts included in the assessment of data and chance were as follows: data organization, representation, interpretation, and chance. Students at this level were expected to interpret data collected by others or themselves. Students must be able to recognize what numbers and points in data mean and how to display data visually in bar and line graphs, and tables. Students were expected to identify and interpret trends in data such as shape, spread, and central tendency. Students must also be able to make

predictions and inferences based on data. Students at this level were expected to have an understanding of probability and the degree of chance; such as more likely, less likely, or equal chance in given situations, (Mullis, TIMSS Assessment Framework, 2009).

Cognitive domains and percentage of items of the assessment at the eighth grade level were as follows: knowing, 35%, applying, 40%, and reasoning, 25%. Concepts included in the assessment of the cognitive domain of knowing were as follows: recall, recognize, compute, retrieve, measure, and order/classify. Students must display a fluency of mathematical knowledge. Concepts included in the assessment in the cognitive domain of applying were as follows: select, represent, model, implement, and solve routine problems. Students were expected to use their mathematic knowledge to solve routine problems familiar to them. Concepts included in the assessment in the cognitive domain of reasoning were as follows: analyze, generalize/specialize, integrate/synthesize, justify, and solve non-routine problems. Students at this level were expected to display intuitive and inductive logical reasoning. Students were also expected to use familiar patterns and mathematic knowledge to solve unfamiliar problems. Problems presented may be real-world situations or hypothetical in nature. Students were expected to make deductions based on mathematical rules and justify their reasoning, (Mullis, Drucker, Preuschoff, Arora, Stanco, 2009).

Contextual Framework of TIMSS Background Questionnaires

Administration of the eighth grade TIMSS included a set of questionnaires completed by all students being assessed, their teachers, the school principals, and the

National Research Coordinator for each country testing. Focus items on the student questionnaire were as follows: self-perceptions about students' home and school lives, basic demographic information, home environment, school climate, and perceptions and attitudes toward learning mathematics and science. Items on the teacher questionnaires focused on their education, professional development, experience teaching, coverage of mathematics content and cognitive curriculum, and instructional activities and material used in the classroom. Items on the school questionnaire filled out by the principals were focused on student demographics, availability of instructional resources, types of programs, and school climate. Questionnaire items answered by the national research coordinator for each participating country focused on the organization and content of mathematics curriculum, (TIMSS, 2011a).

Summary

This chapter has provided a review of the literature and research relevant to the present study. The theoretical framework was explained, and the areas of specific inquiry were reviewed for the sample countries. These included the required credentials of teachers, the mathematics curriculum, and the policy, governance, and finance of education. Also discussed were the contextual frameworks of the TIMSS mathematics assessment and background questionnaires.

CHAPTER 3
METHODOLOGY

Introduction

This chapter contains an explanation of the methods and procedures used to conduct the study. The population and sample are described, and the reliability and validity of the sources of data are discussed. The methods used in data collection and analysis are presented. Also discussed are questions used to elicit information regarding four factors of primary interest: (a) student demographic information; (b) teacher preparation and required credentials; (c) mathematics curriculum and instruction; and (d) legal authority, governance, and finance.

Selection of Participants

Population

The total population of the eighth grade 2011 administration of the TIMSS in mathematics consisted of students who reached their eighth year of schooling beginning with first year of Level 1 education as determined by the International Standard Classification of Education. The total population of students participating in the eighth grade administration of the 2011 TIMSS was 239,423 students. A list of the 63 participating countries can be found in Appendix A.

Sample

The sample in this study was comprised of 25,983 eighth-grade students who participated in the 2011 mathematics administration of the TIMSS in the countries of Singapore, South Korea, Japan, and The United States and represented 1.09% of the total population tested. Numbers and percentages of students participating in the four countries were as follows: Japan, 4,414 (.018%); South Korea, 5,166 (.021%); Singapore, 5,926 (.025%); and the United States, 10,477 (.044%).

Sampling Procedure

The procedure for determining the sample was based on criterion sampling. Three of the four participating countries were ranked in the upper quartile as measured by the 2011 administration of the mathematics portion of the TIMSS for eighth-grade students. The data from these countries were compared to that of the fourth participating country, The United States.

Instrumentation

Validity

The development process was directed and managed by the staff of the TIMSS & PIRLS International Study Center at Boston College in Massachusetts. Staff members collectively had considerable experience in the development of questionnaires and in the measurement and assessment of mathematics, science, and reading achievement.

Also playing a key role in test and questionnaire development were the National Research Coordinators (NRCs) who were designated by the participating countries to be responsible for the complex tasks involved in implementing the studies in their countries. The NRCs and experts from the participating countries developed the test items together with the scoring guides for constructed-response items. They also reviewed the items prior to the field test and, after the field test, select the items for the assessment, (Mullis, Drucker, Preuschoff, Arora, & Stanco (2009).

Reliability

Reliable scoring of the constructed response items was essential for high quality TIMSS data. A high degree of scorer agreement was evidence that scorers applied the scoring guides in the same way. The procedure for scoring the TIMSS 2011 constructed-response items provided for documenting scoring reliability within each country, across countries, and over time.

The method for establishing the reliability of the scoring within each country was for two independent scorers to score a random sample of 200 responses for each constructed-response item twice. The degree of agreement between the scores assigned by the two scorers was a measure of the reliability of the scoring process. In collecting the within-country reliability data, it was vital that the scorers independently scored the items assigned to them. Each scorer did not have prior knowledge of the scores assigned by the other scorer. The within-country reliability scoring was integrated within the main scoring procedure and ongoing throughout the scoring process, (Johansone, 2009).

Cross-country reliability scoring gave an indication about how consistently the scoring guides were applied from one country to the next. The International Association for the Evaluation of Educational Achievement Data Processing and Research Center (IEA DPC) compiled actual responses of students from English speaking countries participating in previous cycles as well as from English-speaking Southern Hemisphere countries participating in the 2011 cycle. Because the Southern Hemisphere collected data in the autumn of 2010, their student responses were available for this exercise. For TIMSS 2011, there were 50 items included at the eighth-grade level. A total of 200 student responses for each item were scanned by the IEA DPC and provided to countries and benchmarking entities on DVDs, (Johansone, 2009).

The purpose of the trend reliability scoring was to measure the reliability of the scoring from one assessment cycle to the next, i.e., from 2007 to 2011for TIMSS. The trend reliability scoring required scorers of the current assessment to score student responses collected in the previous cycle. The scores of the current cycle were then compared with the scores awarded in the previous assessment cycle, (Johansone, 2009).

Data Collection

This study was conducted using multiple sources of documentation: (a) archival data from tests results and (b) background questionnaires. The researcher collected archival test results and information from contextual background questionnaires of international participants. Background questionnaires were completed by utilizing Likert-type scaling to rate participant perceptions and beliefs. Following are descriptions

of the data collection process used for factors concerning (a) student demographic information; (b) teacher preparation and required credentials; (c) legal authority, governance, and finance; and (d) mathematics curriculum and instruction

Factors Concerning Student Demographic Information

As part of the background questionnaires, principals, teachers, and students were asked about factors concerning student demographic information. Factors concerning student demographic information included school emphasis on academic success, the degree of disciplinary problems in the school, the location of the school regarding population of the area, the socioeconomic status of the families within the school, the percentage of students being assessed in their native language, the degree of safety and orderliness in the school, and student perceptions of bullying within the school. Examples of the questionnaire formatting can be found in Appendix B.

Principals and teachers of students participating in the 2011 eighth-grade TIMSS Assessment in Mathematics were asked about school emphasis on academic success. Principals scaled the emphasis the school placed on academic success as having: (a) a very high emphasis, (b) a high emphasis, or (c) a medium emphasis. Answers were reported as the percentage of participating students in each category and the average achievement of those students (Mullis, Martin, Foy, & Arora (2012d).

Principals and teachers were also asked to scale the degree of discipline problems and safety and orderliness within the participating schools. Principals scaled their schools as having: (a) hardly any problems, (b) minor problems, or (c) moderate

problems. Answers were reported as the percentage of students in each category and the average student achievement scores of those students (Mullis, Martin, Foy, & Arora, 2012d).

Principals were also asked about their school location regarding population size of the city, town, or area. Principals responded whether their school was located in an area populated by: (a) more than 100,000 people, (b) 15,001 to 100,000 people, or (c) 15,000 or fewer people. Answers were reported as the percentage of participating students attending the schools in each category and the average achievement scores of those students (Mullis, Martin, Foy, & Arora, 2012d).

Principals of participating schools were asked to report on whether their schools were (a) more affluent, schools where more than 25% of students came from economically affluent homes and not more than 25% came from economically disadvantaged homes; (b) neither more affluent nor more disadvantaged; or (c) more disadvantaged, schools where more than 25% of students came from economically disadvantaged homes and not more than 25% of students came from economically advantaged homes. Answers were reported as the percentage of participating students attending schools in each category and the average achievement scores of those students (Mullis, Martin, Foy, & Arora, 2012d).

Principals were asked to report on the percentage of participating students in their schools that had the language of the test as their native language. Principals answered whether: (a) more than 90% of their students were tested in their native language, (b) between 51% and 90% of their students were tested in their native language, or (c) fewer

than 50% of their students were tested in their native language. Answers were reported as the percentage of participating students in each category and the average achievement scores of those students (Mullis, Martin, Foy, & Arora, 2012d).

Students were asked about their perceptions of how often they were bullied at school. Students scaled themselves as being bullied at school: (a) almost never, (b) about monthly, or (c) about weekly. Answers were reported in the percentage of participating students in each category and the average achievement scores of those students (Mullis, Martin, Foy, & Arora, 2012d). A template used in collecting student demographic data is contained in Appendix C.

Factors Concerning Teacher Preparation and Required Credentials

As part of the background questionnaire, teachers of students participating in the 2011 eighth grade TIMSS Assessment in Mathematics were asked about their levels of formal education, required credentials, professional development, and degree of peer collaboration. Examples of the questionnaire formatting of these questions can be found in Appendix B.

Teachers of participating students were asked about their levels of post-secondary education. Teachers scaled themselves as either having (a) completed a postgraduate university degree, (b) completed a Bachelor's degree or equivalent bot not a postgraduate degree, (c) completed post-secondary education but not a Bachelor's degree, or (d) no further upper secondary education (Mullis, Martin, Foy, & Arora, 2012f).

Teachers were also asked about their major areas of study in college. Teachers scaled themselves as having: (a) major areas of study in both mathematics and mathematics education, (b) major area of study in mathematics education but not mathematics, (c) major area of study in mathematics but not mathematics education, (d) other major area of study, or (e) no formal education beyond upper-secondary. Answers were reported as the percentage of students by teachers holding each type of degree(s) and the average achievement scores of those students, (Mullis, Martin, Foy, & Arora, 2012f).

Teachers were asked about their years of experience teaching. Answers were reported as the percentage of students tested by teachers having each level of years of experience and the average achievement of those students. Teachers scaled themselves as having: (a) 20 years or more experience, (b) at least 10 years but less than 20 years of experience, (c) at least five but less than 10 years of experience, or (4) less than five years of experience. An average number of years teaching experience was also reported for each country in the sample countries (Mullis, Martin, Foy, & Arora, 2012f).

Responding teachers were asked about their participation in professional development in mathematics in the past two years. Answers were reported as the percentage of students tested by teachers participating in mathematics professional development and the average achievement of those students. Teachers scaled themselves as participating in professional development in the areas of: (a) mathematics content, (b) mathematics pedagogy/instruction, (c) mathematics curriculum, (d) integrating information technology into mathematics, (e) improving students' critical thinking or

problem solving skills, or (f) mathematics assessment (Mullis, Martin, Foy, & Arora, 2012f).

Teachers were also asked about their perception of their level of preparedness to teach mathematics topics assessed by TIMSS. Teachers scaled themselves as being "very well" prepared in: (a) overall mathematics (nineteen topics), (b) numbers (five topics), (c) algebra (five topics), (d) geometry (six topics), and (e) data and chance (three topics). Answers were reported as the percentage of students tested by teachers who believed themselves to be "very well" prepared to teach mathematics and the average scores of those students (Mullis, Martin, Foy, & Arora, 2012f).

Teachers were asked about their level of confidence in teaching mathematics. Answers were reported as the percentage of students tested assigned to teachers in each category and the average achievement scores of those students. Teachers scaled themselves as feeling: (a) very confident, or (b) somewhat confident (Mullis, Martin, Foy, & Arora, 2012f).

Teachers were also asked about their confidence levels in specific components of teaching mathematics. Answers are reported as the percentage of students tested assigned to teachers responding in each category and the average scores of those students. Teachers were reported to feel "very confident" to: (a) answer student questions about mathematics, (b) show students a variety of problem solving strategies, (c) provide challenging tasks for capable students, (d) adapt teaching to engage student interests, and (e) help students appreciate the value of learning mathematics (Mullis, Martin, Foy, & Arora, 2012f).

Participating teachers were asked about their level of collaboration with other teachers to improve teaching mathematics. Teachers scaled themselves as being; (a) very collaborative, (b) collaborative, or (c) somewhat collaborative. Answers were reported as the percentage of participating students assigned to teachers in each category and the average achievement scores of those students (Mullis, Martin, Foy, & Arora, 2012f).

Finally, teachers were asked about their level of career satisfaction. Answers were reported as the percentage of students tested assigned to teachers in each category and the average achievement scores of those students. Teachers reported feeling: (a) satisfied, (b) somewhat satisfied, or (c) less than satisfied (Mullis, Martin, Foy, & Arora, 2012f). A template used in collecting the teacher preparation and required credentials data is contained in Appendix C.

Factors Concerning Mathematics Curriculum and Instruction

As part of the background questionnaire, national research coordinators, principals, and teachers were asked about factors of student achievement concerning mathematics curriculum and instruction. These factors of student achievement included: the topics assessed by the TIMSS intended to be taught by the end of eighth grade, how much time was spent on mathematics instruction, various instructional practices, activities, and classroom assessment. Students were also asked about how much time they spend on mathematics homework. The researcher also investigated the department/ministries of education in the countries of the sample for similarities and differences in instructional pedagogy, delivery models, and order of instruction.

National research coordinators were asked about the number of TIMMS mathematics topics that were intended to be taught by the end of eighth grade. National research coordinators responded in terms of all 19 mathematics topics as to: (a) topics taught to all or almost all students, (b) topics taught to only the more able students, or (c) topics not included in the curriculum through eighth grade. Responses were also disaggregated by specific mathematics topics (numbers, algebra, geometry, and data and chance). Answers were reported as number of topics taught, 1-19. A list of topics assessed by TIMSS is found in Appendix B (Mullis, Martin, Foy, & Arora, 2012b).

Principals and teachers were asked how much time, in hours, was spent on mathematics. Responses were reported in terms of the total instructional hours per year and number of hours per year spent on mathematics instruction (Mullis, Martin, Foy, & Arora, 2012b).

Teachers were asked about the percentage of students taught the TIMSS mathematics topics. Results were reported in terms of all 19 mathematics topics; numbers (five topics), algebra (five topics), geometry (six topics), or data and chance (three topics). Answers were reported as the percentages of participating students in each category (Mullis, Martin, Foy, & Arora, 2012b).

Teachers were also asked about how often they used instructional practices to engage students in learning mathematics. Teachers scaled themselves as using instructional practices to engage students in learning mathematics: (a) in most lessons, (b) about half their lessons, or (c) in some lessons. Answers were reported as the percentage

of participating students assigned to those teachers answering in each category and the average achievement scores of those students (Mullis, Martin, Foy, & Arora, 2012b).

Participating teachers were asked about how often they related lessons to students' daily lives and brought interesting material to class. Teachers scaled themselves as relating lessons to students' daily lives as: (a) every lesson or almost every lesson and (b) about half the lessons; and bringing interesting material to class as: (a) every lesson or almost every lesson, and (b) about half the lessons. Answers were reported as the percentage of participating students assigned to those teachers in each category and the average achievement scores of those students (Mullis, Martin, Foy, & Arora, 2012e).

Teachers were asked about how much instructional time was limited by students' lacking prerequisite knowledge or skills. Teachers reported that instructional time was limited: (a) not at all, (b) some, or (c) a lot. Answers were reported as percentages of participating students assigned to teachers reporting in each category and the average achievement scores of those students (Mullis, Martin, Foy, & Arora, 2012b).

Teachers were also asked about instructional time being limited by students suffering from lack of nutrition or sleep. Results were disaggregated into two separate sections for nutrition and sleep. Teachers reported instructional time was limited by the lack of nutrition or sleep as: (a) not all limited, or (b) limited some or a lot. Answers were reported as the percentage of participating students assigned to teachers reporting in each category and the average achievement scores of those students (Mullis, Martin, Foy, & Arora, 2012b).

Teachers were asked about instructional time being limited by disruptive or uninterested students. Results were disaggregated into two sections for disruptive students and uninterested students. Teachers reported whether students were either disruptive or uninterested: (a) some or not at all, or (b) a lot. Answers were reported as the percentage of participating students assigned to teachers reporting in each category and the average achievement scores of those students (Mullis, Martin, Foy, & Arora, 2012b).

Teachers were also asked about the resources they used for teaching mathematics. Results were disaggregated by whether teachers used specific resources as the basis for instruction or as a supplement. Teachers reported they used (a) textbooks, (b) workbooks or worksheets, (c) concrete objects or materials that help students understand quantities or procedures, and (d) computer software for mathematic instruction. Answers were reported as the percentage of teachers reporting in each category (Mullis, Martin, Foy, & Arora, 2012e).

Participating teachers were asked about the instructional activities students used in every, or almost every lesson. Teachers reported instructional activities used were: (a) worked problems (individual or with peers) with teacher guidance, (b) worked problems together in the whole class with direct teacher guidance, (c) worked problems (individually or with peers) while teacher was occupied by other tasks, (d) memorize rules, procedures, or facts, (e) explain answers, or (f) apply facts, concepts, and procedures. Answers were reported as the percentage of participating students engaged in each category (Mullis, Martin, Foy, & Arora, 2012e).

Teachers were asked about the availability of computers for mathematics lessons. Results were reported as the percentage of students who had computers available for mathematics lessons. The average achievement scores for students who both did and did not have computers available for mathematics lessons was also reported. Teachers also reported the percentage of students who had their students use computers for mathematics lessons at least monthly. Teachers reported whether student used computers to: (a) explore mathematics principals and concepts, (b) look up ideas and information, (c) process and analyze data, or (d) practice skills and procedures. These answers were reported as the percentage of participating students in each category, (Mullis, Martin, Foy, & Arora, 2012e).

Teachers were asked about classroom assessment in mathematics. Teachers were asked about how often they assessed students in mathematics and in which mathematical areas. Teachers reported they assessed students: (a) every two weeks or more, (b) about once a month, or (c) a few times a year or less. Teachers reported they assessed students involving the application of mathematical procedures: (a) always or almost always, (b) sometimes, or (c) never or almost never. Teachers reported they assessed students involving searching for patterns and relationships: (a) always or almost always, (b) sometimes, or (c) never or almost never. Teachers reported they assessed students requiring explanation of justification: (a) always or almost always, (b) sometimes or (c) never or almost never. Answers were reported in the percentages of students in each category (Mullis, Martin, Foy, & Arora, 2012b).

Finally, students were asked about how much time per week they spent on mathematics homework. Students reported they spent weekly: (a) three hours or more, (b) more than 45 minutes but less than three hours, or (c) 45 minutes or less. Answers were reported as the percentage of students in each category and the average achievement scores of those students. An example of the questioning format can be found in Appendix B (Mullis, Martin, Foy, & Arora, 2012b). A template for Mathematics Curriculum and Instruction Data Collection is shown in Appendix C.

Factors Concerning Legal Authority, Governance, and Finance

Factors of student achievement concerning legal authority, governance, and finance of the public education systems in the countries of the sample countries included: the structure of governance in the public education systems, in what level of government decisions were made in making education policy such as graduation requirements, teacher required credentials, funding, curriculum guidance, and ensuring equal access to educational opportunity for all students. The structure of each public education system of the sample countries was analyzed, and the use of national curriculum standards within the countries of the sample were discussed along with the national assessments administered in the countries of the sample. Finally, the impact and use of the TIMSS in public education systems in the countries in the sample were considered.

Data Analysis

The data collected in this study were analyzed using a content analysis technique. Data analysis focused on each of the four research questions.

1. What similarities, if any, existed in the student demographic information in the sample with regard to socioeconomic status, student age, gender, total population of students in school, and total population of students tested?
2. What similarities, if any, existed in the order of instruction for mathematics curriculum and delivery models in the sample?
3. What similarities, if any, existed in the required credentials for educators in the sample?
4. What similarities, if any, existed in the policies, governance, and finance of the education systems in the sample?

The TIMSS & PIRLS International Study Center computed item statistics for all achievement items in the 2011 assessments. The item statistics for each of the participating countries were then carefully reviewed. For all items, regardless of format, i.e., multiple choice or constructed response, statistics included the number of students that responded in each country, the difficulty level (the percentage of students that answered the item correctly), and the discrimination index (the point-biserial correlation between success on the item and total score). The item review outputs also listed countries that participated at higher grades as well as all the benchmarking participants. Statistics displayed for multiple choice items included the percentage of students that chose each response option--as well as the percentage of students that omitted or did not

reach the item--and the point-biserial correlations for each response option. Statistics displayed for constructed response items, which could have 1, 2, or 3 score points, included the difficulty and discrimination of each score level. During item review, "not reached" responses, i.e., items toward the end of the booklet that students did not attempt, were treated as "not administered" and did not contribute to the calculation of the item statistics. However, the percentage of students not reaching each item was reported. Omitted responses, although treated as incorrect, were tabulated separately from incorrect responses for the sake of distinguishing students who provided no form of response from students who attempted a response, (Foy, Martin, Mullis, & Stanco, 2009).

Assessment items were scaled using three types of Item Response Test (IRT) models depending on the type of questioning. Dichotomous items, those with either a correct or incorrect answer, were scaled using either a two- or three-parameter IRT model. A two-parameter model was used for true or false questions and a three-parameter model was used for multiple choice questions. The formula used for the two- or three-parameter IRT model was as follows:

$$P\,(xi\ = 1\,\theta k\,, ai\,, bi\,, ci\,) = \ ci\ + \frac{1-c_1}{1+exp(-1.7\cdot ai\cdot(\theta k\,-bi\,))} \equiv\ Pi, 1\,(\theta k\,)$$

x_i is the response to item i, 1 if correct and 0 if incorrect;

θ_k is the proficiency of a student on a scale k (note that a student with higher proficiency has a greater probability of responding correctly);

a_i is the slope parameter of item i, characterizing its discriminating power;

b_i is the location parameter of item i, characterizing its difficulty;

c_i is the lower asymptote parameter of item i, reflecting the chances of students with very low proficiency selecting the correct answer, (Foy et al., 2009).

The probability of an incorrect response to the item was as follows:

$$Pi,0 \;=\; P\,(xi \;=\; 0\,\theta k\,,ai\,,bi\,,ci\,) \;=\; 1 -\; Pi,1\,(\theta k\,)$$

The two-parameter (2PL) model was used for the constructed-response items that were scored as either correct or incorrect. The form of the 2PL model was the same as Equations (1) and (2) with the ci parameter fixed at zero, (Foy et al., 2009).

Polytomous items or those that have more than one possible answer were scored using the Muraki generalized partial credit model as follows:

$$P\,(xi \;=\; l\,\theta k\,,ai\,,bi\,,di,1\,,L,di,mi\; -1\,) = \frac{exp[\sum_{v=0}^{l} 1.7\cdot a_i\cdot\{\theta_k - b_i + d_{i,v}\}]}{\sum_{g=0}^{m_i-1} exp\,[\sum_{v=0}^{g} 1.7\cdot a_i\cdot(\theta_k - b_i + d_{i,v})]} \equiv P_{i,l}(\theta_k)$$

where:

m_i is the number of response categories for item i, usually 3;

x_i is the response to item i, ranging between 0 and mi –1;

θ_k is the proficiency of a student on a scale k;

a_i is the slope parameter of item i;

b_i is its location parameter, characterizing its difficulty;

$d_{i,1}$ is the category *l* threshold parameter, (Foy et al., 2009).

The indeterminacy of model parameters in the polytomous model was resolved by setting

$d_{1,0} \;=\; 0$ and $\sum_{j-1}^{m_1-1} d_{1,j}$ =0, (Foy et al., 2009).

Approval of the Research

Prior to undertaking this research, the approval of the Institutional Review Board (IRB) at the University of Central Florida was sought and received. The research was judged to be exempt from human subject concerns. A copy of the IRB letter of approval is included in Appendix D.

Summary

The total population of students participating in the eighth-grade administration of the 2011 TIMSS was 239,423 students. The sample in this study was 25,983 eighth-grade students participating in the 2011 mathematic administration of the TIMSS in the countries of Singapore, South Korea, Japan, and The United States, representing 1.09% of the total population tested. The procedure for determining the sample was based on criterion sampling. The TIMSS & PIRLS International Study Center at Boston College used a collaborative process to develop the new items needed for the mathematics, science, and reading achievement tests and questionnaires for each cycle of testing in order to validate the assessment. The method for establishing the reliability of the scoring within each country was for two independent scorers to score a random sample of 200 responses for each constructed-response item twice. This study was conducted using multiple sources of documentation, i.e., archival data from tests results and background questionnaires. The TIMSS & PIRLS International Study Center computed item statistics for all achievement items in the 2011 assessments.

CHAPTER 4
ANALYSIS OF THE DATA

Introduction

The data presented in this chapter were organized around the four research questions that guided the study. In the first section of the chapter, comparative student demographics for the four countries of interest are presented. In the second section, the professional characteristics of educators in the four countries are compared. The curricula, including order of instruction, educational pedagogy, and delivery models are compared in the third section. In the fourth section, data regarding the policies, governance, and finance of the four countries are presented.

Student Demographic Information

As part of the background questionnaires, principals, teachers, and students were asked about factors concerning student demographic information. Factors concerning student demographic information included school emphasis on academic success, the degree of disciplinary problems in the school, the location of the school regarding population of the area, the socioeconomic status of the families within the school, the percentage of students being assessed in their native language, the degree of safety and orderliness in the school, and student perceptions of bullying within the school. Examples of the questionnaire formatting can be found in Appendix B.

Sample Size of Participating Schools

For the purposes of this study, a sample of schools that had participated in the 2011 administration of the TIMSS in the four countries being compared were selected. The sample consisted of 501 schools in the United States, 165 schools in Singapore, 150 schools in the Republic of Korea, and 138 schools in Japan. Total participation within the sample schools of the four countries was also calculated for the 8th-grade students comprising the sample. Data were accessed for a total of 10,477 students in the United States, 5,927 students in Singapore, 5,166 students in the Republic of Korea and 4,414 students in Japan. School and student samples sizes by country are displayed in Table 1.

Table 1

School and Student Sample Sizes by Country

	Sample Size	
Country	Schools	Students
Singapore	165	5,927
The Republic of Korea	150	5,166
Japan	138	4,414
The United States	501	10,477

Sample Schools' Emphasis on Academic Achievement

As part of the study, principals and teachers were asked to scale the emphasis their schools placed on academic achievement. Results were scaled as placing (a) a very high emphasis, (b) high emphasis, and (c) medium emphasis. Results were reported as the percentage of students in the participating countries and average achievement of those

students. Table 2 contains the data regarding principal and teacher emphasis on academic achievement for the four countries and internationally.

Table 2

Percentages of Students and Average Scores: Principal and Teacher Emphasis on Academic Achievement

	Very High Emphasis		High Emphasis		Medium Emphasis	
Country	% Students	Average Score	% Students	Average Score	% Students	Average Score
Singapore	11	651	60	614	29	586
Republic of Korea	16	637	56	613	28	597
Japan	2	~ ~	52	580	47	556
United States	15	532	61	515	24	486
International Average	5	506	48	478	47	452

Source. Mullis, Martin, Foy, & Arora (2012d).

In Singapore, principals and teachers of 11% of students reported they placed a very high emphasis on academic achievement. The average student achievement of those students was 651. Principals and teachers of 60% of students reported they placed a high emphasis on academic achievement. The average score of those students was 614. Principals and students of 29% of students reported they placed a medium emphasis on academic achievement. The average score of those students was 586.

In the Republic of Korea principals and teachers of 16% of students reported they placed a very high emphasis, and the average score of those students was 637. Principals and teachers of 56% of students reported they place a high emphasis on academic achievement, and the average score of those students was 613. Principals and teachers of 28% of participating students reported they placed a medium emphasis on academic achievement, and the average score of those students was 597.

In Japan, principals and teachers of 2% of participating students reported placing a very high emphasis on academic achievement. The average score of those student was not statistically significant and was not, therefore, reported. Principals and teachers of 52% of students reported they placed a high emphasis on academic achievement, and the average scores of those students was 580. Principals and teachers of 47% of students reported they placed a medium emphasis on student achievement, and the average score of those students was 556.

In the United States principals and teachers of students of 15% of participating students reported they placed a very high emphasis on academic achievement, and the average score of those students was 532. Principals and teachers of 61% of students reported they placed a high emphasis on academic achievement, and the average score of those students was 515. Principals and teachers of 47% of participating students reported they placed a medium emphasis on student achievement, and the average score of those students was 486.

The international average of principals and teachers reporting a very high emphasis on academic achievement represented 5% of the student population with an

average score of 506. Principals and teachers reporting a high emphasis placed on student achievement represents 48% of students internationally with an average score of 478. Principals and teachers reporting a medium emphasis on academic achievement represent 47% of the international average of students and the average score of those students was 452.

Discipline, Safety and Orderliness in the Sample Schools

The degree of disciplinary problems, safety, and orderliness was reported by the principals of participating countries. In Singapore, the principals of 64% of students reported a safe and orderly school. The average score of those students was 613. The principals of 37% of students reported a somewhat safe and orderly school. The average score of those students was 595. The principals of 2% of students in Singapore reported their schools were not safe but were orderly, but the average score of those students was not statistically significant and, therefore, was not reported.

In the Republic of Korea, principals of 24% of students reported a safe and orderly school environment with an average student score of 615. Principals of 69% of students reported a somewhat safe and orderly school environment with an average score of 603. Principals of 7% of students reported a school environment that was not safe and orderly with an average score of 593.

In Japan, principals of 5% of students reported a safe and orderly school environment with an average score of 589. Principals of 83% of students reported a somewhat safe and orderly school environment with an average student score of 587.

Principals of 12% of students reported a school environment that was not safe and orderly with an average student score of 574.

In the United States, principals of 66% of students reported a safe and orderly school environment with an average student score of 553. Principals of 30% of students reported a somewhat safe and orderly school environment with an average score of 526. Principals of 4% of students reported a school environment that was not safe and orderly with a score of 503.

The international average of principals who reported a safe and orderly school environment represented 45% of participating students with an average score of 479. Principals reporting a somewhat safe and orderly school environment represented 49% of participating students with an average score of 458. Principals reporting a school environment that was not safe and orderly represented 6% of participating students with an average score of 445. Table 3 displays data regarding principals' and teachers' perceptions of school discipline problems, safety, and orderliness in their schools.

Table 3

Percentages of Students and Average Scores: School Discipline Problems, Safety, and Orderliness

Country	Safe and Orderly		Somewhat Safe and Orderly		Not Safe and Orderly	
	% Students	Average Score	% Students	Average Score	% Students	Average Score
Singapore	64	613	37	595	2	~ ~
Republic of Korea	24	615	69	603	7	593
Japan	5	589	83	587	12	574
United States	66	553	30	526	4	503
International Average	45	479	49	458	6	445

Source. Mullis, Martin, Foy, & Arora (2012d).

Location of Participating Schools by Area Population

As part of this study, the location of participating schools was assessed with regard to area population. In Singapore, the average score for 100% of participating students attending schools in areas where the population was 100,000 people or more was 611.

In the Republic of Korea, 87% of participating students attended schools in areas with populations of 100,000 or more and had an average score of 616. Students attending schools with an area population between 15,000 and 100,000 people represented 10% of students tested in that country and had an average score of 594. Students attending school with area populations of 15,000 people or fewer represented 3% of students tested and had an average score of 567.

In Japan, 67% of students attended schools in areas with populations of more than 100,000 people and had an average score of 573. Students attending schools in areas where the population of people was between 15,001 and 100,000 represented 27% of the students tested and had an average score of 567. Students attending schools in areas where the population was 15,000 or fewer people represented 5% of the students tested and had an average score of 515.

In the United States, 30% of students tested attended school in areas where the population was more than 100,000 people and had an average score of 499. Students attending school in areas where the population was between 15,000 and 100,000 people represented 43% of the students tested and had an average score of 516. Students attending school in areas where the population of people was less than 15,000 people represented 27% of students tested with an average score of 515.

The international average of students attending school in areas where the population was more than 100,000 people represented 37% of the students tested with an average score of 484. Students attending school in areas where the population was between 15,001 and 100,000 represented 28% of all students tested with an average score of 463. Students attending schools in areas where the population of people was less than 15,000 represented 35% of students tested with an average score of 450. Table 4 displays the percentage of students and the average scores of the respective countries included in the study

Table 4

Percentages of Students and Average Scores: Location of School by Area Population

	More Than 100,000		15,001 – 100,000		15,000 or Fewer	
Country	% Students	Average Score	% Students	Average Score	% Students	Average Score
Singapore	100	611	0	~ ~	0	~ ~
Republic of Korea	87	616	10	594	3	567
Japan	67	573	27	567	5	551
United States	30	499	43	516	27	515
International Average	37	484	28	463	35	450

Source. Mullis, Martin, Foy, & Arora (2012d).

School Composition: Student Economic Background

Part of the background study conducted for each country yielded information on school composition by students' economic background. Each country was polled on the percentage of students attending schools that were (a) more affluent (more than 25% of students come from economically affluent homes and not more than 25% from economically disadvantaged homes), (b) neither more affluent nor disadvantaged, or (c) more disadvantaged (those where more than 25% of students come from economically disadvantaged homes and not more than 25% come from more affluent homes.)

In Singapore, 27% of students tested attended more affluent schools and had an average score of 643. Students attending schools that were neither more affluent nor disadvantaged represented 61% of students tested with an average score of 604. Students

attending more disadvantaged schools represented 11% of students tested with an average score of 569.

In the Republic of Korea, 18% of students attended schools that were more affluent and had an average score of 653. Students attending schools that were neither more affluent nor disadvantaged represented 51% of students tested with an average score of 612. Students attending disadvantaged schools represented 32% of students tested with an average score of 591.

In Japan, 46% of students attended more affluent schools with an average score of 582. Students attending schools that were neither affluent nor disadvantaged represented 44% of students tested with an average score of 564. Students attending more disadvantaged schools represented 10% of students tested with an average score of 548.

In the United States, 22% of students tested attended more affluent schools and had an average score of 543. Students attending schools that were nether affluent nor disadvantaged represented 23% of students tested with an average score of 526. Students attending more disadvantaged schools represented 55% of students tested and had an average score of 490.

The international average of students attending more affluent schools was 32% of students tested with an average score of 494. Students attending schools that were neither more affluent nor disadvantaged represent 33% of students tested with an average score of 471. Students attending schools that were more disadvantaged represented 36% of students tested with an average score 448. Table 5 contains data for school composition by economic background.

Table 5

Percentages of Students and Average Scores: School Composition by Student Economic Background

	More Affluent Schools Where More than 25% of Students Come from Economically Affluent Homes and Not More than 25% from Economically Disadvantaged Homes		Neither More Affluent nor Disadvantaged		More Disadvantaged - Schools Where More than 25% of Students Come from Economically Disadvantaged Homes and Not More than 25% from Economically Affluent homes	
Country	% Students	Average Score	% Students	Average Score	% Students	Average Score
Singapore	27	643	61	604	11	569
Republic of Korea	18	653	51	612	32	591
Japan	46	582	44	564	10	548
United States	22	543	23	526	55	490
International Average	32	494	33	471	36	448

Source. Mullis, Martin, Foy, & Arora (2012d).

Students Who Speak the Language of the Test at Home

As part of the background study conducted for the 2011 administration of the TIMSS, the percentage of students who spoke the language of the test at home was assessed. Participating countries reported percentages of students who always or almost always, sometimes, or never spoke the language of the test at home.

In Singapore, 57% of students always or almost always spoke the language of the test at home. The average score of these students was 622. Students who sometimes

spoke the language of the test at home represented 38% of students tested with an average of 597. Students who never spoke the language of the test at home represented 5% of the students tested with an average score of 592.

In the Republic of Korea, 100% of students spoke the language of the test at home and had an average score of 613. The percentages of students who either sometimes or never spoke the language of the test at home were not significant and were not included in the report.

In Japan, 99% of students spoke the language of the test at home. The average score of these students was 569. Students who only sometimes spoke the language of the test at home represented 1% of the students tested. The average scores of these students and those who never spoke the language of the test at home were not significant and were not included in the report.

In the United States, 91% of students tested spoke the language of the test. The average score of these students was 513. Students who sometimes spoke the language of the test represented 8% of the students tested with an average score of 487. Students who never spoke the language of the test represented 1% of students tested. The average score of those students was not significant and was not included in the report.

The international average of students who always or almost always spoke the language of the test at home was 79% of students tested, and they had an average score of 469. Students who sometimes spoke the language of the test represented 17% of students tested with an average score of 443. Students who never spoke the language of the test represented 4% of the students tested with an average score of 421. Table 6 displays the

percentages and average scores for students in the four countries as to whether they spoke the language of the test at home.

Table 6

Percentages of Students and Average Scores: Students Speak the Language of the Test at Home

	Always or Almost Always		Sometimes		Never	
Country	% Students	Average Score	% Students	Average Score	% Students	Average Score
Singapore	57	622	38	597	5	592
Republic of Korea	100	613	0	~ ~	0	~ ~
Japan	99	569	1	~ ~	0	~ ~
United States	91	513	8	487	1	~ ~
International Average	79	469	17	443	4	421

Source. Mullis, Martin, Foy, & Arora (2012d).

Students' Perceptions of Bullying

Student perception of bullying was studied as part of the background assessment of the 2011 administration of the TIMSS. Students reported their perceptions of being bullied as (a) almost never, (b) about monthly, or (c) about weekly.

In Singapore, 52% of students reported they were almost never bullied. These students had an average score of 618. The percentage of students who reported being bullied about monthly was 36% with an average score of 609. The percentage of students who reported being bullied about weekly was about 12% with an average score of 589.

In the Republic of Korea, 65% of students reported almost never being bullied. These students had an average score of 613. Students who reported being bullied about monthly was 28% with an average score of 616. Students who reported being bullied about weekly was 7% with an average score of 603.

In Japan, 63% of students reported almost never being bullied. These students had an average score of 566. Students who reported being bullied about monthly was 28% with an average score 576. Students who reported being bullied about weekly was 9% with an average score of 562.

In the United States, 63% of students reported almost never being bullied. These students had an average score of 513. Students who reported being bullied about monthly was 28% with an average score of 510. Students who reported being bullied about weekly was 9% with an average score of 496.

The international average of students who reported almost never being bullied was 59%. These students had an average score of 473. Students who reported being bullied monthly was 29% with an average score of 467. Students who reported being bullied about weekly was 12% with an average score of 441. Table 7 displays the percentages and average scores of students as to their perceptions of being bullied in their schools.

Table 7

Percentages of Students and Average Scores: Students' Perceptions of Bullying

	Almost Never		About Monthly		About Weekly	
Country	% Students	Average Score	% Students	Average Score	% Students	Average Score
Singapore	52	618	36	609	12	589
Republic of Korea	65	613	28	616	7	603
Japan	63	566	28	576	9	562
United States	63	513	28	510	9	496
International Average	59	473	29	467	12	441

Source. Mullis, Martin, Foy, & Arora (2012d).

Teacher Preparation and Required Credentials

As part of the background questionnaire, teachers of students participating in the 2011 eighth grade TIMSS Assessment in Mathematics were asked about their levels of formal education, required credentials, professional development, and degree of peer collaboration. Examples of the questionnaire formatting of these items can be found in Appendix B.

Teacher Preparation in Singapore

The education system in Singapore is almost entirely governed and funded by the Ministry of Education, Singapore. Although most countries require an undergraduate degree to obtain an initial teaching certification, Singapore requires all prospective

teachers to hold a master's degree. Mathematics and Science teachers in secondary schools and junior colleges must hold master's degrees in their respective fields, (TIMSS & PIRLS, 2011). After graduation, prospective teachers must complete a one-year postgraduate program with the National Institute of Education (NIE). Teacher candidates may opt to complete an additional four-year degree program through the NIE to earn a Bachelor of Arts or science in education. The teaching program offered by the NIE is aligned to the national curriculum.

The Ministry of Education in Singapore emphasizes continuing professional development. All teachers are entitled to participate in 100 hours of professional development in their content curriculum, pedagogical innovation, and new ideas in assessment. The government also provides professional development leading to additional bachelors and masters degrees. In 2003, the Teacher-Worked Attachment Program was established to allow teachers to participate in experiential learning in research laboratories. Through this program, professionals in the business sector are able to partner with educators for the purpose of demonstrating required knowledge in the workforce for future employees. Beginning in 2010, the Ministry established the implementation of a national professional learning community to foster a culture of teacher-led professional excellence and fraternity (TIMSS & PIRLS, 2011).

Teacher Preparation in the Republic of Korea

Prospective teachers in South Korea have been required to complete a four-year degree program in education. Primary grade teachers usually attend one of 11 national university teaching programs. Secondary grade teachers attend either one of the 11 national university teaching programs or graduate schools of education. Prospective teachers also complete a practicum while participating in college coursework. Pre-service teachers are categorized as "Grade II" teachers and are qualified to teach in the public school system. At the conclusion of teacher pre-service, teachers must successfully complete a three-stage Teacher Qualifying Examination. The three stages of the examination include a written examination on curriculum and pedagogy, an essay demonstrating pedagogical knowledge, and an interview (TIMSS & PIRLS, 2011). After a third year of service, teachers must participate in 180 hours of professional development during the summer and winter school break to qualify for reclassification to "Grade II".

Teacher Preparation in Japan

The education system in Japan has functioned as a centralized system in which the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan, under the direction of the national government, regulates standards of teacher preparation and accreditation. Teacher training in Japan began in much the same way as in The United States--with the establishment of normal schools. In 1886, upper normal schools

were created. Elementary teachers were trained in normal schools. Normal school teachers or secondary education teachers were trained in upper normal schools.

According to the National Institution for Education Research [NIER] (2013) undergraduate teacher preparation programs are offered in 582 (79.8%) of 729 higher education institutions. Graduate programs for teacher preparation are offered in 423 (70.9%) of 597 graduate schools. Preliminary teacher training courses are offered in 277 (71.9%) of 385 of junior colleges.

The Ministry of Education in Japan offers three types of teaching certificates: a regular teaching certificate, a special teaching certificate, and a temporary teaching certificate. The regular teaching certificate is the most often awarded and is considered the traditional pathway to education. The regular teaching certificate is issued by the prefectural board upon completion of required teaching programs at an accredited university. Although regular teaching certificates are issued by individual prefectural boards, they are valid in all prefectures in Japan. The regular teaching certificate is valid for 10 years and is renewed by the successful completion of a certification course administered at the university. Regular teaching certificates are categorized into types (Advanced, Type I and Type II) depending on teachers' academic backgrounds. Teachers holding a master's degree are awarded an advanced certificate; teachers with a bachelor's degree are awarded a Type I certificate; and teachers holding an associate's degree are awarded a Type II certificate, (NIER, 2013).

Special teaching certificates were introduced by the Ministry of Education as the result of a revision of the Act on the Certification of Educational Staff in 1988. The

purpose of the Special Teaching Certificate was to provide opportunity for professionals with degrees in subjects other than education to teach. A special certificate may be issued after an interview and upon recommendation of the prospective employer. Whereas regular certificates are valid in all prefectures in the country, special certificates are only valid in the prefecture in which they are awarded. The special teaching certificate is valid for a 10-year period and may be renewed upon successful completion of a certification course.

Temporary teaching certificates may be issued when a prospective employee does not meet all requirements for a regular teaching certificate. Temporary teaching certificates are valid for three years in the prefecture in which they are awarded.

Teacher Preparation in the United States

Due to the United States leaving education systems to be state-level initiatives, each state has had varying requirements for the preparation of educators. In general, there have been two ways to earn a professional teaching license in the United States. The first is a liberal arts based approach in which the focus of the preparation is on the philosophy and pedagogy of education. In this circumstance, students earn education degrees. Upon graduation, they must pass a state professional educator examination and a subject-specific examination in order to earn a professional teaching certificate.

The second approach to earning a professional teaching certificate is to earn a bachelor's degree in a subject other than education and pass a subject-specific education examination. The student may then apply for a temporary teaching certificate. Upon the

issuance of the temporary teaching certificate, the student must complete a rigorous set of professional development courses in educational philosophy and pedagogy. The student must pass the state professional educator's examination before being issued a professional service contract, (USDOE, 2013).

Professional educators must be recertified every five years. Each state has different requirements for recertification, but in general requirements for recertification include participation in continuing professional development. Most state- and district-based professional development courses are offered at no charge. Many state and national education conferences can be paid for with the application and award of grants sponsored by professional organizations. Continuing education opportunities are available for professional educators. The federal government offers subsidized or reimbursement for educators seeking advanced degrees in critical shortage areas such as mathematics, the sciences, English as a second language, and special education services (USDOE, 2013).

Analysis of Background Questionnaires Regarding Teacher Preparation

Teachers' Highest Levels of Education

Part of the background study of the 2011 administration of the TIMSS focused on the percentage of students by teachers' highest level of education. Countries reported the percentages of students who were taught by teachers who had (a) completed a postgraduate university degree, (b) completed a bachelor's degree or equivalent but not a

postgraduate degree, (c) completed post-secondary education but not a bachelor's degree, or (d) had no further than an upper-secondary level education.

In Singapore, 10% of students tested were assigned to teachers who had completed a postgraduate university degree. The percentage of students who were assigned to teachers who completed a bachelor's degree or equivalent, but not a postgraduate degree, was 87%. Students who were assigned to teachers who completed post-secondary education, but had not earned a bachelor's degree, was 2%. The percentage of students assigned to teachers who had no further than an upper-secondary level of education was insignificant and not reported.

In the Republic of Korea, 37% of students were assigned to teachers who had completed a postgraduate university degree. The percentage of students assigned to teachers who completed a bachelor's degree or equivalent was 63%. The percentage of students assigned to teachers who either completed a post-secondary degree or had no more than an upper-secondary level of education was insignificant.

In Japan, 9% of students were assigned to teachers who had completed a postgraduate university degree. The percentage of students who were assigned to teachers who had completed a bachelor's degree was 91%. The percentage of students who were assigned to teachers who completed a post-secondary level of education was 1%. The percentage of students assigned to teachers with no further than an upper-secondary level of education was insignificant.

In the United States, 62% of students were assigned to teachers who had completed a postgraduate university degree. The percentage of students assigned to

teachers who had completed a bachelor's degree was 38%. The percentages of students assigned to teachers who had completed either a post-secondary level of education or no further than an upper-secondary level of education was insignificant.

The international average of students assigned to teachers who had completed a postgraduate university degree was 24%. The percentages of students assigned to teachers who had completed a bachelor's degree was 63%; to teachers who had completed a post-secondary education, 11%; and to teachers with no further than an upper-secondary level of education, 3%. Table 8 displays the percentages of students by teachers' education level.

Table 8

Percentages of Students: Teachers' Highest Levels of Education

Country	Completed a Postgraduate University Degree	Completed Bachelor's Degree or Equivalent but Not a Postgraduate Degree	Completed Post-secondary Education but Not a Bachelor's Degree	No Further than Upper-secondary Education
Singapore	10%	87%	2%	0%
Republic of Korea	37%	63%	0%	0%
Japan	9%	91%	1%	0%
United States	62%	38%	0%	0%
International Average	24%	63%	11%	3%

Source. (Mullis, Martin, Foy, & Arora, 2012f).

Teachers' Major Areas of Study

Part of the background study of the 2011 administration of the TIMSS focused on the percentage of students assigned to teachers by their areas of major study. The study looked at teachers who had (a) major areas of study in both primary education and mathematics, (b) a major area of study in primary education but not mathematics, (c) major area of study in mathematics but not primary education, and (d) major areas of study in all other areas.

In Singapore, 32% of students were assigned to teachers who had major areas of study in both primary education and mathematics. The average scores of these students was 620. The percentage of students assigned to teachers who had major areas of study in primary education but not mathematics was 6% with an average score of 584. The percentage of students assigned to teachers who had major areas of study in mathematics but not primary education was 45%, and the average score was 620. The percentage of students assigned to teachers who had major areas of study in any other areas was 17% with an average score of 585.

In the Republic of Korea, 7% of students were assigned to teachers who had major areas of study in both primary education and mathematics and had an average score of 620. The percentage of students assigned to teachers who had major areas of study in primary education but not mathematics was 49% with an average score of 610. The percentage of students assigned to teachers who had a major area of study in mathematics but not primary education was 42% with an average score of 613. Only 2%

of students were assigned to teachers with major areas of study in other areas. The average score of these students was insignificant and not included in the report.

In Japan, 46% of students tested were assigned to teachers who had major areas of study in both primary education and mathematics. The average score of these students was 577. The percentage of students assigned to teachers with a major area of study in primary education but not mathematics was 7% of students tested with an average score of 556. The percentage of students assigned to teachers who had a major area of study in mathematics but not primary education was 35% of students tested with an average score of 567. The percentage of students who were assigned to teachers who had a major area of study in any other areas was 12% of students tested with an average score of 557.

In the United States, 28% of students tested were assigned to teachers who had major areas of study in both primary education and mathematics. The average score of these students was 524. The percentage of students assigned to teachers who had a major area of study in primary education but not in mathematics was 25% of students tested with an average score of 510. The percentage of teachers assigned to teachers who had a major area of study in mathematics but not primary education was 15% of students tested with an average score of 497. The percentage of students assigned to teachers who had major areas of study in other areas was 31% of students tested with an average score of 510.

The international average of students assigned to teachers with major areas of study in both primary education and mathematics was 32% with an average score of 471. The percentage of students assigned to teachers with a major area of study in primary

education but not mathematics was 12% of students tested with an average score of 470. The percentage of students assigned to teachers with a major area of study in mathematics but not primary education was 41% of students tested with an average score of 468. The percentage of students assigned to teachers who had major areas of study in other areas was 31% of students tested with an average score of 510. Table 9 presents the data for the percentages of students and their average scores by teachers' major areas of study.

Table 9

Percentages of Students and Average Scores: Teachers' Major Areas of Study

	Major in Primary Education and Major (or Specialization) in Mathematics		Major in Primary Education but No Major (or Specialization) in Mathematics		Major in Mathematics but No Major in Primary Education		All Other Majors	
Country	% Students	Average Score	% Students	Average Score	% Students	Average Score	% Students	Average Score
Singapore	32	620	6	584	45	620	17	585
Republic of Korea	7	620	49	610	42	613	2	~ ~
Japan	46	577	7	556	35	567	12	557
United States	28	524	25	510	15	497	31	510
International Average	32	471	12	470	41	468	31	510

Source. Mullis, Martin, Foy, & Arora (2012f).

Teachers' Years of Experience

Part of the background study focused on the percentage of students assigned to teachers by their years of experience. Teachers were polled to find out whether they had (a) 20 or more years of experience, (b) at least 10 but less than 20 years of experience, (c) at least 5 but less than 10 years of experience, or (d) at least five years of experience. The national average of teaching experience in years was also listed for each participating country.

In Singapore, 10% of students tested were assigned to teachers with more than 20 years of experience. The average score of these students was 618. The percentage of students assigned to teachers with at least 10 but less than 20 years of experience was 16% with an average score of 619. The percentage of students assigned to teachers with at least 5 but less than 10 years of experience was 26% of students tested with an average score of 624. The percentage of students assigned to teachers with at least five years of teaching experience was 47% of students tested with an average score of 601. The national average of teaching experience in Singapore was eight years.

In the Republic of Korea, 34% of students were assigned to teachers with more than 20 years of experience. These students had an average score of 618. The percentage of students assigned to teachers with at least 10 years but less than 20 years of experience was 22% of students tested with an average score of 616. The percentage of students assigned to teachers with at least five years but less than 10 years of experience was 17% of students tested with an average score of 625. The percentage of students assigned to

teachers with at least five years of teaching experience was 27% of students tested with an average score of 594. The national average of teaching experience was 13 years.

In Japan, 47% of students tested were assigned to teachers with more than 20 years of teaching experience. These students had an average score of 576. The percentage of students assigned to teachers with at least 10 but less than 20 years of experience was 18% of students tested with an average score of 558. The percentage of students assigned to teachers with at least five but less than 10 years of experience was 17% of the students tested with an average score of 575. The percentage of students assigned to teachers with at least five years of teaching experience was 18% with an average score of 559. The national average of teaching experience in Japan was 17 years.

In the United States, 26% of students were assigned to teachers with more than 20 years of teaching experience. These students had an average score of 519. The percentage of students assigned to teachers with at least 10 but less than 20 years of experience was 28% of students tested with an average score of 517. The percentage of students assigned to teachers with at least five but less than 10 years of experience was 28% of students tested with an average score of 506. The percentage of students assigned to teachers with at least five years of teaching experience was 17% with an average score of 505. The national average of teaching experience in the United States was 14 years.

The international average of students assigned to teachers with more than 20 years of experience was 36% of students tested with an average score of 474. The percentage of students assigned to teachers with at least 10 but less than 20 years of experience is 28% of students tested with an average score of 470. The percentage of students assigned

to teachers with at least five but less than10 years of teaching experience was 19% of students tested with an average score of 463. The percentage of students assigned to teachers with at least five years of teaching experience was 17% of students tested with an average score of 458. The international average of teaching experience was 16 years. Table 10 displays the data for percentages and average scores of students by teachers' years of experience.

Table 10

Percentages of Students and Average Scores: Teachers' Years of Experience

	20 Years or More		At Least 10 but Less Than 20 Years		At Least 5 but Less than 10 Years		At Least 5 Years		National Average
Country	% Students	Average Score	% Students	Average Score	% Students	Average Score	% Students	Average Score	Years of Teaching
Singapore	10	618	16	619	26	624	47	601	8
Republic of Korea	34	618	22	616	17	625	27	594	13
Japan	47	576	18	558	17	575	18	559	17
United States	26	519	28	517	28	506	17	505	14
International Average	36	474	28	470	19	463	18	458	16

Source. Mullis, Martin, Foy, & Arora (2012f).

Teachers' Areas of Participation in Professional Development

Part of the background study of the TIMSS administration focused on the percentage of students assigned to teachers by the teachers' areas of participation in professional development. Areas of professional development assessed were (a) mathematics content, (b) mathematics pedagogy/instruction, (c) mathematics curriculum, (d) integrating information technology into mathematics, (e) improving students' critical thinking or problem solving, and (f) mathematics assessment.

In Singapore, 67% of students tested were assigned to teachers who participated in mathematics content professional development. The following percentages of students were assigned to teachers who participated in the respective areas of professional development: mathematics pedagogy/instruction (79%), mathematics curriculum (55%); integrating information technology into mathematics (68%), improving students' critical thinking or problem solving skills (4%), and mathematics assessment (58%).

In the Republic of Korea, 51% of students tested were assigned to teachers who participated in mathematics content professional development. The following percentages of students were assigned to teachers who participated in the respective areas of professional development: mathematics pedagogy/instruction (79%), mathematics curriculum (53%), integrating information technology into mathematics (27%), improving students' critical thinking or problem solving skills (32%), and mathematics assessment (46%).

In Japan, 66% of students tested were assigned to teachers who participated in mathematics content professional development. The following percentages of students were assigned to teachers who participated in the respective areas of professional development: mathematics pedagogy/instruction (70%), mathematics curriculum (41%), integrating information technology into mathematics (23%), improving students' critical thinking or problem solving skills (33%), and mathematics assessment (26%).

In the United States, 73% of students were assigned to teachers participating in mathematics content professional development. The following percentages of students were assigned to teachers who participated in the respective areas of professional development: mathematics pedagogy/instruction (73%), mathematics curriculum (78%), integrating information technology into mathematics (68%), improving students' critical thinking or problem solving skills (61%), and mathematics assessment (61%).

The international average of students assigned to teachers participating in mathematics content professional development was 55% of students. The following percentages of students were assigned to teachers participating in the respective areas of professional development: mathematics pedagogy/instruction (58%), mathematics curriculum (52%), integrating information technology into mathematics (48%), improving students' critical thing or problem solving skills (43%), and mathematics assessment (47%). Table 11 contains the percentages of students taught by teachers engaged in selected areas of professional development.

Table 11

Percentages of Students Taught by Teachers Engaged in Selected Professional Development

Country	Mathematics Content	Mathematics Pedagogy/Instruction	Mathematics Curriculum	Integrating Information Technology into Mathematics	Improving Students' Critical Thinking or Problem Solving Skills	Mathematics Assessments
Singapore	67%	79%	55%	68%	4%	58%
Republic of Korea	51%	61%	53%	27%	32%	46%
Japan	66%	70%	41%	23%	33%	26%
United States	73%	73%	78%	68%	61%	61%
International Average	55%	58%	52%	48%	43%	47%

Source. Mullis, Martin, Foy, & Arora (2012f).

Teachers Preparedness to Teach TIMSS Mathematics Topics

Another part of the background study of the TIMSS focused on the percentage of students assigned to teachers who felt very well prepared to teach TIMSS mathematics topics. The study focused on (a) overall mathematics, 19 topics; (b) numbers, 5 topics; (c) algebra, 5 topics; (d) geometry, 6 topics; and (e) data and chance, 3 topics.

In Singapore, 86% of students were assigned to teachers who felt very well prepared to teach overall mathematics. The following percentages of students were assigned to teachers who felt very well prepared to teach the other TIMSS mathematics topics: numbers (96%), algebra (89%), geometry (85%), data and chance (73%).

In the Republic of Korea 79% of students were assigned to teachers who felt very well prepared teach overall mathematics topics. The following percentages of students were assigned to teachers who felt very well prepared to teach the other TIMSS mathematics topics: numbers (88%), algebra (86%), geometry (82%), data and chance (46%).

In Japan 67% of students tested were assigned to teachers who felt very well prepared to teach overall mathematics topics. The following percentages of students were assigned to teachers who felt very well prepared to teach the other TIMSS mathematics topics: numbers (79%), algebra (69%), geometry (74%), data and chance (32%).

In the United States 94% of students were assigned to teachers who felt very well prepared to teach the overall mathematics topics. The following percentages of students

were assigned to teachers who felt very well prepared to teach the other TIMSS mathematics topics: numbers (98%), algebra (96%), geometry (93%), data and chance (83%).

The international average of students assigned to teachers who felt very well prepared to teach the overall mathematics topics was 84% of students tested. The following percentages of students were assigned to teachers who felt very well prepared to teach the other TIMSS mathematics topics: numbers (92%), algebra (87%), geometry (85%), data and chance (62%). Table 12 displays the percentages of students whose teachers believed they were very well prepared to teach the TIMSS mathematics topics.

Table 12

Percentages of Students Whose Teachers Feel "Very Well" Prepared to Teach TIMSS Mathematics Topics

	Percentages				
Country	Overall Mathematics (19 Topics)	Numbers (5 Topics)	Algebra (5 Topics)	Geometry (6 Topics)	Data and Chance (3 Topics)
Singapore	86%	96%	89%	85%	73%
Republic of Korea	79%	88%	86%	82%	46%
Japan	67%	79%	69%	74%	32%
United States	94%	98%	96%	93%	83%
International Average	84%	92%	87%	85%	62%

Source. Mullis, Martin, Foy, & Arora (2012f).

Teachers' Level of Confidence in Teaching Mathematics

The background study of the TIMMS also focused on the percentage of students assigned to teachers according to teachers' level of confidence in teaching mathematics. Teachers reported feeling either very confident or somewhat confident. Results were reported as the percentage of students assigned to teachers and students' average scores.

In Singapore, 59% of students were assigned to teachers who reported feeling very confident in teaching mathematics. The average score of these students was 603. The percentage of students assigned to teachers feeling somewhat confident in teaching mathematics was 41% of students tested with an average score of 623.

In the Republic of Korea, students assigned to teachers feeling very confident in teaching mathematics was 50% of students tested with an average score of 613. The percentage of students assigned to teachers who felt somewhat confident in teaching mathematics was also 50% of those tested with an average score of 613.

In Japan, teachers who felt very confident in teaching mathematics were assigned 36% of students tested. These students had an average score of 577. Teachers who felt somewhat confident in teaching mathematics were assigned 64% of the students tested with an average score of 566.

In the United States, the percentage of students assigned to teachers who felt very confident in teaching mathematics was 86% of students tested. They had an average score of 514. Teachers who felt somewhat confident in teaching mathematics were assigned 14% of students tested and had an average score of 503.

The international average of teachers who felt very confident in teaching mathematics were assigned 76% of students tested. These students had an average score of 470. Teachers who felt somewhat confident in teaching mathematics were assigned 24% of students tested and had an average score of 456. Table 13 displays the percentages of students and average scores related to teachers' confidence in teaching mathematics.

Table 13

Percentages of Students and Average Scores: Teachers' Confidence in Teaching Mathematics

	Very Confident		Somewhat Confident	
Country	% Students	Average Score	% Students	Average Score
Singapore	59	603	41	623
Republic of Korea	50	613	50	613
Japan	36	577	64	566
United States	86	514	14	503
International Average	76	470	24	456

Source. Mullis, Martin, Foy, & Arora (2012f).

Teachers' Level of Confidence in Responding to Student Questions

The background study of the TIMSS focused on the percentage of students assigned to teachers who felt very confident to answer questions about mathematics, show students a variety of problem solving strategies, and provide challenging tasks for capable students. The study also focused on the percentage of students assigned to teachers who felt very confident to adapt teaching to engage student interests and help students appreciate the value of learning mathematics.

In Singapore, 89% of students tested were assigned to teachers who felt very confident to answer student questions about mathematics. The percentage of students assigned to teachers who felt very confident to show students a variety of problem solving strategies was 71% of students tested. Teachers who felt very confident in their ability to provide challenging tasks for capable students were assigned 51% of students, and those who felt very confident in adapting their teaching to engage student interests were assigned 41% of students tested. The percentage of students tested assigned to teachers who felt very confident in helping students appreciate the value of learning mathematics was 35% of students tested.

In the Republic of Korea, the percentage of students assigned to teachers who felt very confident to answer student questions about mathematics was 72% of students tested. Teachers who felt very confident in showing students a variety of problem solving strategies were assigned 55% of those tested, and those who felt very confident in their ability to provide challenging tasks for capable students were assigned 46% of students tested. The percentage of students assigned to teachers who felt very confident

in adapting their teaching to engage student interests was 36%. The percentage of students assigned to teachers who felt very confident in helping students appreciate the value of learning mathematics was also 36% of students tested.

In Japan, 74% of students tested were assigned to teachers who felt very confident in answering student questions about mathematics. The percentage of students assigned to teachers who felt very confident in showing students a variety of problem solving strategies was 46% of students tested. Teachers who felt very confident in their ability to provide challenging tasks for capable students were assigned 36% of students tested. Teachers who felt very confident in their ability to adapt their teaching to engage student interests were assigned 27% of students tested. Students assigned to teachers who felt very confident in helping students appreciate the value of learning mathematics was 21% of students.

In the United States, 97% of teachers felt very confident in answering student questions about mathematics. The percentage of students assigned to teachers who felt very confident in showing students a variety of problem solving strategies was 91% of students tested. Teachers who felt very confident in their ability to adapt teaching to engaging student interests were assigned 65% of students tested. Teachers who felt very confident in helping students appreciate the value of learning mathematics were assigned 65% of students tested.

The international average of teachers who felt very confident in answering student questions about mathematics were assigned 87% of students tested. The percentage of students assigned to teachers who felt very confident in showing students a variety of

problem solving strategies was 77% of students tested. The percentage of students assigned to teachers who felt very confident in providing challenging tasks for capable students was 65% of students. Teachers who felt very confident in adapting teaching to engage student interests were assigned 62% of students tested. Teachers who felt very confident in helping students appreciate the value of learning mathematics were assigned 65% of students tested. Table 14 reflects the percentages of students assigned to teachers who felt very confident in responding to questions and assisting their students by using varied strategies to support their learning.

Table 14

Percentages of Students: Teachers Who Feel Very Confident in Answering Students' Questions

Country	Answer Student Questions About Mathematics	Show Students a Variety of Problem Solving Strategies	Provide Challenging Tasks for Capable Students	Adapt Teaching to Engage Student Interests	Help Students Appreciate the Value of Learning Mathematics
Singapore	89%	71%	51%	41%	35%
Republic of Korea	72%	55%	46%	36%	36%
Japan	74%	46%	36%	27%	21%
United States	97%	91%	76%	65%	67%
International Average	87%	77%	65%	62%	65%

Source. Mullis, Martin, Foy, & Arora (2012f).

Teachers' Levels of Career Satisfaction

Part of the background study of the TIMSS focused on the percentage of students assigned to teachers according to teachers' levels of career satisfaction. Teachers reported to feeling (a) satisfied, (b) somewhat satisfied, or (c) less than satisfied. The average student score was also reported for each category.

In Singapore, 29% of students were assigned to teachers who reported feeling satisfied with their careers. The average scores of these students was 634. The percentage of students assigned to teachers feeling somewhat satisfied was 62% of students tested with an average score of 603. The percentage of students assigned to teachers who felt less than satisfied with their careers was 9% of students tested with an average score of 597.

In the Republic of Korea, 11% of students, with an average score of 610, had been assigned to teachers who felt satisfied with their careers. The percentage of students assigned to teachers who felt somewhat satisfied with their careers was 67% of students. They had an average score of 616. Teachers who were less than satisfied with their careers were assigned 22% of students, and they had an average score of 602.

In Japan, 25% students were assigned to teachers who were satisfied with their careers. These students had an average score of 588. A total of 63% of the students were assigned to teachers who were somewhat satisfied with their careers. Their average score was 566. Teachers who were less than satisfied with their careers were assigned 12% of students tested, and they had an average score of 552.

In the United States, 48% of students tested were assigned to teachers who felt satisfied with their careers. The average score of these students was 515. The percentage of students assigned to teachers who felt somewhat satisfied with their careers was 43% of students tested, who had an average score of 510. Teachers who felt less than satisfied with their careers were assigned 9% of students tested with an average score of 503.

The international average of teachers who felt satisfied with their careers were assigned 47% of students tested. These students had an average score of 473. The percentage of students assigned to teachers who felt somewhat satisfied with their careers was 45% with an average score of 464. The percentage of students assigned to teachers who were less than satisfied with their careers was 7% with an average score of 462. Table 15 displays the percentage of students and their average scores when teachers' levels of career satisfaction were considered.

Table 15

Percentages of Students and Average Scores: Teacher Career Satisfaction

Country	Satisfied		Somewhat Satisfied		Less Than Satisfied	
	% Students	Average Score	% Students	Average Score	% Students	Average Score
Singapore	29	634	62	603	9	597
Republic of Korea	11	610	67	616	22	602
Japan	25	588	63	566	12	552
United States	48	515	43	510	9	503
International Average	47	473	45	464	7	462

Source. Mullis, Martin, Foy, & Arora (2012f).

Teachers' Level of Collaboration with Peers

In Singapore, the 17% of students tested were assigned to teachers who were very collaborative with their peers. The average score of those students was 611. The percentage of students assigned to teachers who were collaborative with their peers was 70% of students tested with an average score of 610. Teachers who were somewhat collaborative were assigned 13% of students tested and had an average score of 616.

In the Republic of Korea, 15% of students tested were assigned to teachers who were very collaborative with their peers. The average achievement of those students was 613. The percentage of students assigned to teachers who were collaborative with their peers was 62% of students tested with an average score of 613. Teachers who were

somewhat collaborative with their peers were assigned 23% of students tested with an average score of 610.

In Japan, 15% of students tested were assigned to teachers who were very collaborative with their peers. The average achievement of those students was 572. The percentage of students assigned to teachers who were collaborative with their peers was 61% of students tested with an average score of 569. Teachers who were somewhat collaborative with their peers were assigned 24% of students tested with an average score of 571.

In the United States, 39% of students tested were assigned to teachers who were very collaborative with their peers. The average score of these students was 509. The percentage of students assigned to teachers who were collaborative with their peers was 40% of students tested with an average score of 510. Teachers who were somewhat collaborative with their peers were assigned 22% of students tested with an average score of 520.

The international average of students assigned to teachers who were very collaborative with their peers was 28% of students tested. These students had an average score of 467. The percentage of students who were assigned to teachers who were collaborative with their peers was 57% of students tested with an average score of 468. Teachers who were somewhat collaborative with their peers were assigned 15% of students tested with an average score of 465. Table 16 displays the percentages of students and their average scores reflecting teachers' levels of collaboration with their peers.

Table 16

Percentages of Students and Average Scores: Teachers' Levels of Collaboration with Peers

Country	Very Collaborative		Collaborative		Somewhat Collaborative	
	% Students	Average Score	% Students	Average Score	% Students	Average Score
Singapore	17	611	70	610	13	616
Republic of Korea	15	613	62	613	23	610
Japan	15	572	61	569	24	571
United States	39	509	40	510	22	520
International Average	28	467	57	468	15	465

Source. Mullis, Martin, Foy, & Arora (2012f).

Mathematics Curriculum and Instruction

As part of the background questionnaire, national research coordinators, principals, and teachers were asked about factors of student achievement concerning mathematics curriculum and instruction. These factors of student achievement included: the topics assessed by the TIMSS intended to be taught by the end of eighth grade, how much time was spent on mathematics instruction, various instructional practices, activities, and classroom assessment. Students were also asked about how much time they spent on mathematics homework.

Mathematics Curriculum in Sample Countries

Mathematics Curriculum in Singapore

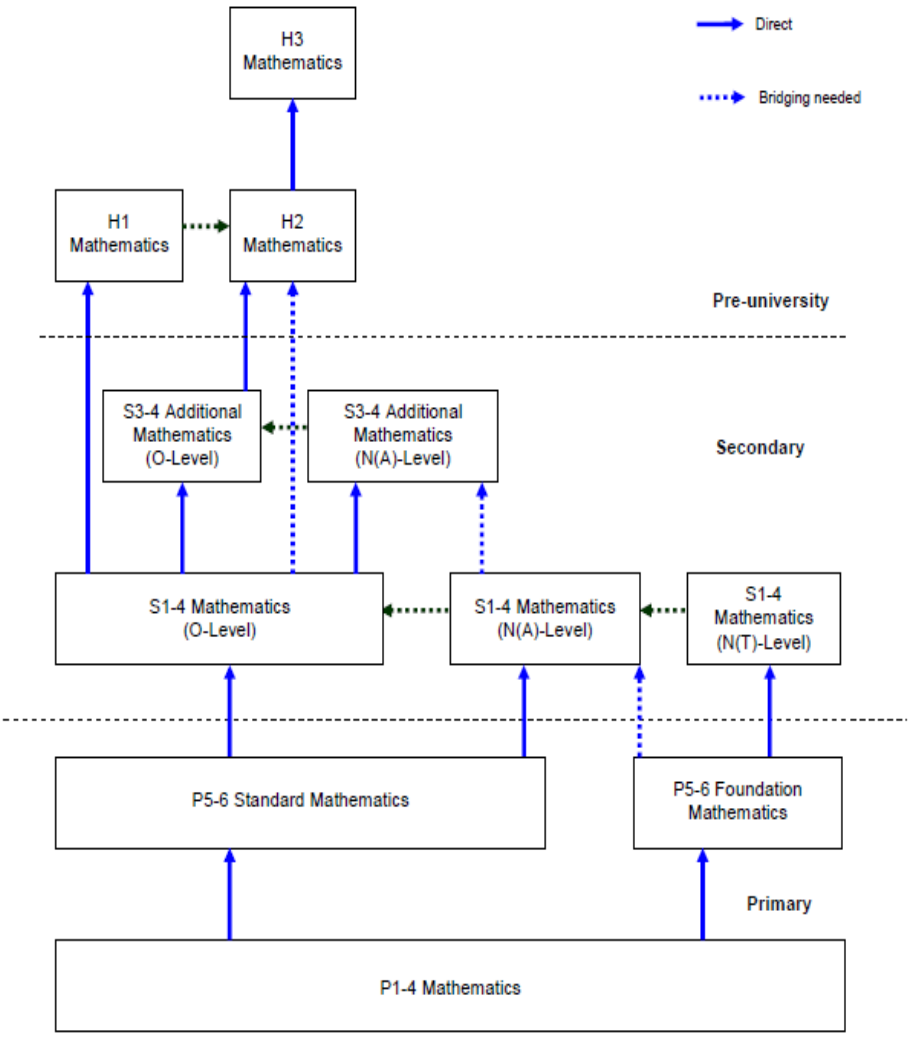
The public education system in Singapore operates under a Ministry of Education which controls all aspects of education including school administration, a national curriculum, and teacher training. The national curriculum of Singapore has been focused on 21st century skills and student performance on national examinations and international examinations including TIMSS and PISA. At the time of this research, national primary syllabi were being revised with an estimated release date between 2013 and 2018. At present, there were six domains of mathematical knowledge being addressed in the curriculum from Grades 1-12: numbers and algebra, geometry and measurement, statistics and probability, algebra, geometry and trigonometry, and calculus. In Primary 1-4, all students participate in homogenous grouped classes covering the same strands in a spiraled instructional method. Primary 5 and 6 also cover the same strands but are separated into groups based on ability. Primary 5 and 6 Foundations remediates and builds on skills learned in Primary 1-4, and Primary 5 & 6 Standard builds upon skills learned in Primary 1-4. Lower secondary grades include three strata of mathematics education based on student ability. Secondary Grades 1-4 O Level build upon the strands learned in Primary 5and 6 Standard. Secondary Grades 1-4 N (A) Level contain a subset of strands from O Level and also remediate skills learned in Primary 5 and 6 Standard. Secondary Grades 1-4 N (T) Level build upon skills learned in Primary Grades 5 and 6 Foundations. Secondary Grades 1-4 Level mathematics courses are considered the core course of study and mark the end of compulsory education by the time students turn 15

years of age. Student in Secondary Grades 3 and 4 who wish to participate in additional mathematics education may choose to take two mathematics elective: Secondary 3-4 N (A) Level Additional and Secondary 3-4 O Level Additional. Secondary 3-4 N (A) Level Additional remediates a subset of strands from Secondary level 1-4 O Level and the prerequisites for Level H2 mathematics at the pre-university level. Secondary Grade 3-4 O Level Additional builds in-depth upon skills learned in Secondary Grades 1-4 O Level and prepares students for Level H1 mathematics at the pre-university level. There are three levels of mathematics education at the pre-university level, which marks the final stage of the public education system in mathematics. Level H1-H3 classes are elective courses designed for students who wish to pursue mathematics-based professions. Table 17 represents the strands covered in each of the three domains of knowledge for the primary and secondary grade levels in Singapore, and Figure 1 illustrates the structure of the mathematics curriculum (Ministry of Education, Singapore, 2013).

Table 17

Mathematical Domains and Strands Required by the Ministry of Education in Singapore

	Strands					
Domains	Primary Grades 1-4	Secondary Grades 1-4 O Level	Secondary Grades 1-4 N(A) Level	Secondary Grades 1-4 N(T) Level	Secondary Grades 3-4 Additional O Level	Secondary Grades 3-4 Additional N(A) Level
Numbers and Algebra	23	41	42	26		
Geometry and Measurement	4	16	12	14		
Statistics and Probability	1	3	3	4		
Algebra					20	15
Geometry and Trigonometry					19	14
Calculus					18	16



Note.

Figure 1. Organizational Structure of Mathematics Curriculum in Singapore, Ministry of Education, Singapore, 2012.

Mathematics Curriculum in the Republic of Korea

The public education system in South Korea began with the development of a democratic government at the end of Japanese colonization in 1945. The Ministry of Education in South Korea went through a period of quantitative expansion in the 1960s and 1970s with an increase of student population, number of schools, and number of teachers. In the 1980s, there was a period of qualitative expansion in the public education system as evidenced by educational reform (Ministry of Education, Science and Technology, South Korea, 2013).

At the time of the present study, the general mathematics curriculum in South Korea consisted of mathematics concepts and applications that were taught in primary and secondary grades. Specific domains taught in each grade level were not made available by the Ministry of Education; however, the number of units corresponding to minutes of instruction in each 34-week school year, (Ministry of Education, Korea, 2013). Table 18 contains a display of the number of minutes of instruction for both mathematics concepts and application in primary and secondary grades. Table 19 shows the units of mathematics concepts and applications that are taught in secondary grades.

Table 18

Minutes of Mathematics Instruction in Primary and Secondary Grades in South Korea

	Primary Grades						Middle Grades			Upper Secondary Grades		
	1	2	3	4	5	6	7	8	9	10	11	12
Minutes	120	136	136	136	136	136	136	136	102	136	Selected Subjects	

Table 19

Units of Mathematics Concepts and Applications Taught in Secondary Grades in South Korea

National Basic Curriculum	General Subjects	Advanced Subjects
Math (8)	Math Application (4)	Math I(8), Math II(8), Differential and Integral Calculus(4), Probability and Statistics(4), Discrete Mathematics(4)

Mathematics Curriculum in Japan

The current system of public education in Japan was established in 1947 during the period of occupation by The United States military after World War II. The public education system is headed by the Ministry of Education which controls school administration, curriculum, pedagogy, and the content of national textbooks. The Ministry of Education is also in control of the appointment of municipal boards of education and superintendents. Due to American occupation at the time, the development of the public education system was largely influenced by American systems. The leaders of Japanese education sent their scholars and theorists to The United States and England

to learn educational pedagogy. Though the approaches to curriculum have been varied, much of the theory of education and pedagogy has been similar in the United States and Japan. The Japanese system of public education consists of six years of elementary school, three years of lower-secondary school, three years of academically stratified upper-secondary school, and four years of specialized post-secondary school, (Ishikida, 2005).

In the United States, between 30 and 35 topics are typically covered each year within 17 domains of knowledge in Kindergarten through Grade 12. Japanese schools cover about 10 topics per year in four domain clusters within Grades 1-6, 7-9, and 10-12. Table 20 contains the mathematical domains required by the Ministry of Education, Culture, Sports, Science and Technology of Japan [MEXT] (2013) in Grades 1-12.

Major differences in curriculum are in the way instruction has been delivered. Educators in Japan have used many of the same methods as their American counterparts, e.g., delivering instruction in whole groups, small groups, and individually. Japanese educators have also diversified the delivery style of instruction between lecture-based, guided practice, individualized practice, and the use of traditional methods as well as constructivist methods (MEXT, 2013)

Table 20

Mathematical Domains Required by the Ministry of Japan

	Grade											
Domains	1	2	3	4	5	6	7	8	9	10	11	12
Numbers and Calculations	X	X	X	X	X	X						
Quantities and Measurement	X	X	X	X	X	X						
Quantitative Relations	X	X	X	X	X	X						
Geometric Figures	X	X	X	X	X	X	X	X	X			
Numbers and Mathematic Expressions							X	X	X			
Functions							X	X	X			
Data Handling							X	X	X			
Quadratic Functions										X	X	X
Trigonometry Ratios										X	X	X
Permutations and Combinations										X	X	X
Probability										X	X	X

Another major difference in the delivery of instruction between the United States and Japan has been in the number of topics addressed annually (30-35 in American schools). Because of this, U.S. teachers are able to provide a brief overview of the topics each year with the understanding that in a subsequent year the topic will be spiraled back at a deeper level. In Japan, the practice supported by the Ministry of Education has been to teach fewer topics to mastery of all students each year. Once the topics are mastered, they are not included in the curriculum again. Because concepts are taught to mastery and not reintroduced, less time each year is devoted to relearning what was forgotten the

previous year. By Grade 8, mathematics textbooks in Japan are approximately two years above the level of American textbooks, (Schueller, n.d.).

The focus on homework is another difference in America's and Japan's mathematics curricula. Japanese educators assign more homework than their American counterparts but spend much less time reviewing it during class time. Because the concepts are not spiraled through the curriculum each year and much less time is focused on activating or relearning prior knowledge, the priority of Japanese mathematics curriculum is to focus on new content and to teach it to the point of mastery for all students.

Mathematics Curriculum in the United States

In the United States, mathematics curriculum is driven by two major pieces of federal legislation; The No Child Left Behind Act and The Race to the Top Act. The purpose of these two acts is to bring mathematics education in the United States more in line with a national curriculum and, therefore, be able to provide an equal education to all students regardless of location. The education system in the United States is not centralized, as individual states have ultimate authority over matters of education. It is important to have as much cohesion as possible rather than wild diversity in educational standards among states. With this in mind, two non-governmental agencies, The National Governors Association Center for Best Practices (NGACBP) and The Council of Chief State School Officers (CCSSO) have led the development of the Common Core State Standards. This initiative has been supported by the federal government via the

provision of funds for implementation to states that choose to adopt the standards. Currently 46 states have adopted the use of Common Core State Standards. Alaska, Texas, Minnesota, and Virginia had not adopted the standards at the time of the 2011 data acquisition. The purpose of developing Common Core State Standards was to provide minimum requirements to which participating states in the United States would agree to meet.

In the common core, the scope of mathematics curriculum in the United States encompasses 17 domains. A total of 11 domains are covered in Kindergarten through Grade 8: counting and cardinality, numbers and operations in base ten, numbers and operations in fractions, operations in algebraic thinking, measurement and data, geometry, ratios and proportional relationships, and the number system, expressions and equations, functions, and statistics and probability. Mathematics curriculum in high school encompasses the following six domains: number and quantity, algebra, functions, modeling, geometry, and statistics and probability. Table 21 provides a tabular display of the domains in the common core taught in each grade level from kindergarten through high school.

Table 21

Mathematical Domains Taught in K-12 in Common Core

	Grades									
Domains	K	1	2	3	4	5	6	7	8	High School
Counting/ Cardinality	X									
Operations & Algebraic Thinking	X	X	X	X	X	X				
Numbers and Operations in Base Ten	X	X	X	X	X	X				
Numbers and Operations in Fractions				X	X	X				
Measurement and Data	X	X	X	X	X	X				
Geometry	X	X	X	X	X	X	X	X	X	
Ratios and Proportional Relationships							X	X	X	
The Number System							X	X	X	
Expressions and Equations							X	X	X	
Statistics and Probability							X	X	X	
Number and Quantity										X
Algebra										X
Functioning										X
Modeling										X
Geometry										X
Statistics and Probability										X

Analysis of Background Questionnaires Regarding Mathematics Curriculum

Instructional Practices to Engage Students in Learning Mathematics

Part of the background study of the TIMSS focused on how often teachers used instructional practices to engage students in learning mathematics. Results were reported in terms of the percentage of students tested assigned to teachers using these practices (a) in most lessons, (b) about half their lesson, or (c) some lessons. The student score representing the average level of achievement was also reported.

In Singapore, 63% of students were assigned to teachers who used engaging instructional practices in most lessons. The average score of these students was 615. The percentage of students assigned to teacher who use engaging instructional practices in about half their lessons was 27% of students tested with an average score of 609. Teachers who used engaging instructional practices in some of their lessons were assigned 10% of students tested with an average score of 594.

In the Republic of Korea, 65% of students tested were assigned to teachers who used engaging instructional practices in most of their lessons. These students had an average score of 616. The percentage of students assigned to teachers who used engaging instructional practices in about half of their lessons was 28% of students tested with an average score of 609. Teachers who used engaging instructional practices in some of their lesson were assigned 7% of students tested with an average score of 594.

In Japan, 55% of students tested were assigned to teachers who used engaging instructional practices in their lessons. The average score of these students was 571. The

percentage of students assigned to teachers who used engaging instructional practices in about half of their lessons was 38% of students tested with an average score of 567. Teachers who used engaging instructional practices in some of their lessons were assigned 6% of students tested with an average score of 573.

In the United States, 93% of students tested were assigned to teachers who used engaging instructional practices in most lessons. The average score of those students was 511. The percentage of students who were assigned to teachers who used engaging instructional practices in about half of their lesson was 7% of students tested with an average score of 526. There were no reported students assigned to teachers who used engaging instructional practices in only some of their lessons.

The international average of students assigned to teachers who used engaging instructional practices in most of their lessons was 80%of students tested. These students had an average score of 469. The percentage of students assigned to teachers who used engaging instructional practices in about half of their lessons was 17% of students tested with an average score of 459. The international average of teachers who used engaging instructional practices in only some of their lessons was 3% of students tested with an average score of 484. Table 22 reflects the percentages and scores of students when calculated based on teachers' instructional practices to engage students in learning mathematics.

Table 22

Percentages of Students and Average Scores: Teachers' Instructional Practices to Engage Students in Learning Mathematics

Country	Most Lessons		About Half the Lessons		Some Lessons	
	% Students	Average Score	% Students	Average Score	% Students	Average Score
Singapore	63	615	27	609	10	594
Republic of Korea	65	616	28	609	7	598
Japan	55	571	38	567	6	573
United States	93	511	7	526	0	~ ~
International Achievement	80	469	17	459	3	484

Source. Mullis, Martin, Foy, & Arora (2012b).

Relevance of Lessons to Students' Daily Lives

A portion of the background study of the TIMSS focused on how often teachers related lessons to students' daily lives and brought interesting material to class. Teachers reported whether they engaged in these practices in (a) every, or almost every lesson or (b) half their lesson or less. Results were reported as the percentage of students assigned to these teachers and their average achievement score.

In Singapore, teachers who related their lessons to the lives of their students in every lesson were assigned 16% of students tested. The average score of these students was 605. The percentage of students assigned to teachers who related lessons to their lives in half or less of their lessons was 84% of students tested with an average score of 613. The percentage of students assigned to teachers who brought interesting material to

class for almost every lesson was 4% of students tested with an average score of 601. The percentage of students assigned to teachers who brought interesting material to class for half or less of their lessons was 96% of students tested with an average score of 612.

In the Republic of Korea, 21% of students were assigned to teachers who related their lessons to the lives of the students in almost every lesson. These students had an average score of 617. Students assigned to teachers who related their lessons to students' lives in half or less of their lessons was 79% of students tested with an average score of 611. Teachers who brought interesting materials to class for almost every lesson were assigned 15% of students tested with an average score of 617. Teachers who brought interesting material to class for half or less of their lessons were assigned 85% of students tested with an average score of 612.

In Japan, 10% of students tested were assigned to teachers who reported relating their lessons to the lives of their students in almost every lesson. The average score of these students was 575. Students assigned to teachers who related their lessons to the lives of their students in half or less of their lessons was 90% of students tested with an average score of 520. Teachers who brought interesting material for almost every lesson were assigned 5% of students tested with an average score of 576. Teachers who brought interesting materials for half or less of their lessons were assigned 95% of students tested with an average score of 569.

In the United States, 40% of students tested were assigned to teachers who reported relating almost every lesson to the lives of their students. These students had an average score of 499. The percentage of students assigned to teachers who related half or

less of their lessons to the lives of their students was 60% of students tested with an average score of 520. Teachers who brought interesting materials to class for almost all their lessons were assigned 18% of students tested with an average score of 511. Teachers who brought interesting materials to class for half or less of their lessons were assigned 82% of students tested with an average score of 512.

The international average of teachers who related their lessons to the lives of their students in almost every lesson was 39% of students tested. The average score of those students was 467. Teachers who related half or less of their lessons to the lives of their students were assigned 61% of students tested with an average score of 468. The percentage of students assigned to teachers who brought interesting material to class for almost every lesson was 18% of students tested with an average score of 469. The percentage of students assigned to teachers who brought interesting material to class for half or less of their lessons was 82% of students tested with an average score of 467. Table 23 displays percentages and scores of students based on their teachers' relating lessons to students' daily lives and the use of interesting class materials.

Table 23

Percentages of Students and Average Scores: Teachers' Relating Lessons to Students' Daily Lives and Use of Interesting Class Materials

	Relate Lessons to Students' Lives				Bring Interesting Materials to Class			
	Every or Almost Every Lesson		Half the Lessons or Less		Every or Almost Every Lesson		Half the Lessons or Less	
Country	% Students	Average Score	% Students	Average Score	% Students	Average Score	% Students	Average Score
Singapore	16	605	84	613	4	601	96	612
Republic of Korea	21	617	79	611	15	617	85	612
Japan	10	575	90	569	5	576	95	569
United States	40	499	60	520	18	511	82	512
International Average	39	467	61	468	18	469	82	467

Source. Mullis, Martin, Foy, & Arora (2012e).

Instructional Time Limitations

Students Lacking Prerequisite Knowledge or Skills

Part of the background study focused on how much instructional time was limited by students lacking prerequisite knowledge or skills. Teachers were queried as to having instructional time limited (a) not at all, (b) some or (c) a lot. Results were reported as the percentage of students assigned to those teachers in each category and students' average score representing their level of academic achievement.

In Singapore, 22% of students tested were assigned to teachers who reported that no instructional time was lost due to limited prerequisite knowledge. The average score

of those students was 659. The percentage of students assigned to teachers who reported some instructional time lost due to students lacking knowledge was 64% of students tested with an average score of 605. The percentage of students assigned to teachers reporting a lot of instructional time being lost due to students lacking prerequisite knowledge was 14% of students tested with an average score of 516.

In the Republic of Korea, 30% of students tested were assigned to teachers who reported no instructional time lost with an average score of 623. Teachers who reported some instructional time lost due to lack of prerequisite knowledge taught 52% of students tested with an average score of 612. Teachers who reported a lot of instructional time lost due to lack of student knowledge taught 18% of students tested with an average score of 598.

In Japan, 42% of students tested were assigned to teachers who reported no instructional time lost due to lack of prerequisite knowledge. These students had an average score of 590. The percentage of students assigned to teachers who reported some instructional time lost due to a lack of skills was 53% with an average score of 557. Teachers who reported a lot of instructional time lost due to a lack of student skills were assigned 6% of students tested with an average score of 538.

In the United States, 12% of students tested were assigned to teachers who reported no instructional time lost due to lack of prerequisite knowledge. The average scores of those students was 566. The percentage of students assigned to teachers who reported some instructional time lost was 59% of students tested with an average score of 516. The percentage of students assigned to teachers who reported a lot of instructional

time lost due to a lack of prerequisite knowledge was 29% of students tested with an average score of 480.

The international average of students assigned to teachers who reported no instructional time lost due to lack of prerequisite knowledge was 15% of students tested. The average score of those students was 490. The percentage of students assigned to teachers who reported some instructional time lost was 57% of students tested with an average score of 471. The percentage of students assigned to teachers who reported a lot of instructional time lost due to lack of prerequisite skills was 28% of students tested with an average score 443. Table 24 displays the percentages and scores of students based on teachers' reports of instructional time lost due to students' lack of prerequisite knowledge or skills.

Table 24

Percentages of Students and Average Scores: Instructional Time Lost Due to Students' Lack of Prerequisite Knowledge or Skills

	Not At All		Some		A Lot	
	% Students	Average Score	% Students	Average Score	% Students	Average Score
Singapore	22	659	64	605	14	516
Republic of Korea	30	623	52	612	18	598
Japan	42	590	53	557	6	538
United States	12	566	59	516	29	480
International Average	15	490	57	471	28	443

Source. Mullis, Martin, Foy, & Arora (2012b).

Students Suffering from Lack of Nutrition or Sleep

Another portion of the background study focused on how much instructional time was limited due to students suffering from lack of nutrition or sleep. Teachers reported the limitation of instructional time due to lack of nutrition or sleep as (a) not at all or (b) some or a lot. Results were reported as the percentage of students assigned to these teachers and their average scores.

In Singapore, 87% of students tested were assigned to teachers who reported no limitation to instruction due to lack of nutrition. The average score of these students was 616. The percentage of students assigned to teachers who reported either some or a lot of limitations to instruction due to the lack of nutrition was 13% of students tested with an average score of 576. Teachers who reported no limitation to instruction due to lack of sleep were assigned 31% of students tested with an average score of 627. Teachers who reported either some or a lot of limitations of instruction due to lack of sleep were assigned 69% of students tested with an average score of 603.

In the Republic of Korea, 72% of students tested were assigned to teachers who reported no limitations to instructional time due to lack of nutrition. The average score of the students was 616. The percentage of students assigned to teachers who reported some or a lot of limitations to instruction due to lack of nutrition was 28% of students tested with an average score of 605. Teachers who reported no limitation to instruction due to lack of sleep were assigned 37% of students tested with an average score of 616. Teachers who reported some or a lot of limitations to instruction due to lack of sleep were assigned 63% of students tested with an average score of 611.

In Japan, 99% of students tested were assigned to teachers who reported no limitation of instruction due to lack of nutrition. The average score of these students was 570. Teachers who reported some or a lot of limitations to instruction due to lack of nutrition were assigned 1% of the students tested. The average score of these students was not significant and was, therefore, not reported. Teachers who reported no limitations to instruction due to lack of sleep were assigned 66% of students tested with an average score of 571. Teachers who reported some or a lot of limitations to instruction due to lack of sleep were assigned 34% of students tested with an average score of 566.

In the United States, 68% of students tested were assigned to teachers who reported no limitations to instructional time due to lack of nutrition. These students had an average score of 523. The percentage of students assigned to teachers who reported some or a lot of limitations to instruction due to lack of nutrition was 32% of students tested with an average score of 487. Teachers who reported no limitations to instruction due to lack of sleep were assigned 22% of students tested. The average score of these students was 543. Teachers who reported some or a lot of limitations to instruction due to lack of sleep were assigned 78% of students tested with an average score of 503.

The international average of teachers who reported no limitations to instruction due to lack of nutrition was 63% of students tested. These students had an average score of 477. Teachers who reported some or a lot of limitations to instruction due to lack of nutrition were assigned 375 of students tested with an average score of 449. The percentage of students assigned to teachers who reported no limitations to instruction due

to lack of sleep was 43% of students tested with an average score of 447. The percentage of students assigned to teachers who reported some or a lot of limitations to instruction due to lack of sleep was 57% of students tested with an average score of 461. Table 25 displays the perceptions of teachers regarding instructional time limitations resulting from students' lack of sleep and nutrition.

Table 25

Percentages of Students and Average Scores: Instructional Time Limited by Students Suffering From Lack of Nutrition or Sleep

	Lack of Nutrition				Lack of Sleep			
	Not At All		Some or A Lot		Not At All		Some or A Lot	
Country	% Students	Average Score	% Students	Average Score	% Students	Average Score	% Students	Average Score
Singapore	87	616	13	576	31	627	69	603
Republic of Korea	72	616	28	605	37	616	63	611
Japan	99	570	1	~ ~	66	571	34	566
United States	68	523	32	487	22	543	78	503
International Average	63	477	37	449	43	447	57	461

Source. Mullis, Martin, Foy, & Arora (2012b).

Disruptive or Uninterested Students

As part of the background study, teachers were polled on how much instructional time was limited due to disruptive or uninterested students. Results were reported as the percentage of students tested who were assigned to teachers who either said instructional time was (a) some or not at all limited or (b) limited a lot.

In Singapore, 88% of students tested were assigned to teachers who reported with some or no limitations due to student disruptions. The average score of these students was 617. The percentage of students assigned to teachers who reported a lot of limitations due to disruptive students was 12% of students tested with an average score of 568. Teachers who reported some or no limitations due to uninterested students taught 87% of students tested with an averages score of 618. Teachers who reported a lot of limitations due to uninterested students taught 13% of students with an average score of 561.

In the Republic of Korea, 60% of students tested were assigned to teachers who reported some to no limitations due to disruptive students with an average score of 618. Students assigned to teachers who reported a lot of limitations due to disruptive students totaled 40% of students tested with an average score of 604. Teachers who reported some to no limitations due to uninterested students taught 71% of students tested with an average score of 620. Teachers who reported a lot of limitations due to uninterested students taught 29% of students tested with an average score of 594.

In Japan, 99% of students tested had been assigned to teachers who reported some to no limitations due to disruptive students. These students had an average score of 570.

Teachers who reported a lot of limitations due to disruptive students taught only 1% of students tested. The average score of these students was insignificant and was not reported. Teachers who reported some to no limitations due to uninterested students were taught 96% of students tested with an average score of 571. The percentage of students assigned to teachers who reported a lot of limitations due to uninterested students was 4% of students tested with an average score of 544.

In the United Sates, 86% of students tested were assigned to teachers who reported some to no limitations due to disruptive students. The average score of these students was 518. Teachers who reported a lot of limitations due to disruptive students taught 14% of students tested with an average score of 472. The percentage of students assigned to teachers who reported some to no limitations in instruction due to uninterested students was 81% of students tested with an average score of 518. Teachers who reported a lot of limitations due to uninterested students taught 19% of students tested with an average score of 485.

The international average of teachers who reported some to no limitations due to disruptive students taught 83% of students tested. These students had an average score of 472. Teachers who reported a lot of limitations due to disruptive students were assigned to 17% of students with an average score of 444.The percentage of students assigned to teachers who reported some to no limitations to instruction due to uninterested students was 76% of students tested with an average score of 475. The percentage of students assigned to teachers who reported a lot of limitations due to uninterested students was 24% of students tested with an average score of 441. Table 26 contains the percentages

of students and their average scores who were assigned to teachers who either said instructional time was (a) some or not at all limited or (b) limited a lot by disruptive or uninterested students.

Table 26

Percentages of Students and Average Scores: Instructional Time Limited by Disruptive or Uninterested Students

	Limited by Disruptive Students				Limited by Uninterested Students			
	Some or Not At All		A Lot		Some or Not At All		A Lot	
	% Students	Average Score	% Students	Average Score	% Students	Average Score	% Students	Average Score
Singapore	88	617	12	568	87	618	13	561
Republic of Korea	60	618	40	604	71	620	29	594
Japan	99	570	1	~ ~	96	571	4	544
United States	86	518	14	472	81	518	19	485
International Average	83	472	17	444	76	475	24	441

Source. Mullis, Martin, Foy, & Arora (2012b).

Resources Used by Teachers to Teach Mathematics

Part of the background study focused on resources used by teachers to teach mathematics. Teachers were polled as to how they used textbooks, workbooks/worksheets, concrete objects or materials, and computer software as part of

their instruction. Results are reported in terms of percentages of students assigned to reporting teachers.

In Singapore, 59% of students tested were assigned to teachers who reported using textbooks as the basis for instruction, and 39% were assigned to teachers who used texts as supplemental material. The percentage of students assigned to teachers who reported using workbooks/worksheets as the basis for their instruction was 51% of students tested, but 48% were assigned to teachers who used them as supplemental material. The percentage of students assigned to teachers who said they used concrete objects or other materials as the basis for their instruction totaled only 10% of the students tested, but 85% were assigned to teachers who used them as supplemental material. Teachers who reported using computer software as the basis for their instruction were assigned to 11% of students tested, but those who used computer software as supplemental material were assigned to 82% of students tested.

In the Republic of Korea, 97% of students were assigned to teachers who said they used textbooks as the basis for instruction, and only 3% were assigned to teachers who use them as supplemental material. The percentage of students assigned to teachers who said they use workbook/worksheets as the basis of instruction was 68% of students tested, and 32% were assigned to teachers who used them as supplemental material. The percentage of students assigned to teachers who said they used concrete objects or materials as the basis for instruction was 17% of students tested, and 77% were assigned to teachers who used them as supplemental materials. Teachers who said they used

computer software as the basis for their instruction were assigned to 14% of students tested, but 69% were assigned to teachers who used them as supplemental materials.

In Japan, 83% of students tested were assigned to teachers who said they used textbooks as the basis for their instruction. In contrast, 15% were assigned to teachers who used them as supplemental material. The percentage of students assigned to teachers who said they used workbooks/worksheets as the basis of instruction was 22% of the students tested. Teachers who used them as supplemental materials were assigned 75% of students tested. The percentage of students assigned to teachers who said they used concrete objects or other materials as the basis for instruction was 10% of the students tested, but 80% were assigned to teachers who used them as supplemental materials. There were no reported students assigned to teachers who said they used computer software as the basis for their instruction, but 27% of students were assigned to teachers who used computer software as supplemental material.

In the United States, 48% of students tested were assigned to teachers who said they used textbooks as the basis for their instruction. Slightly less, 43%, were assigned to teachers who use them as supplemental material. The percentage of students assigned to teachers who said they used workbooks/worksheets as the basis for their instruction was only 19% of students tested. A majority, 77%, were assigned to teachers who used them as supplemental materials. The percentage of students assigned to teachers who said they used concrete objects or other materials as their basis of instruction was 17% of students tested, but 75% were assigned to teachers who used them as supplemental materials. Teachers who reported using computer software as the basis for their instruction were

assigned 14% of students tested, and 62% were assigned to teachers using them as supplemental materials.

The international average of teachers who said they used textbooks as the basis for their instruction were assigned to 77% of students tested, and 21% were assigned to teachers who used textbooks as supplemental materials. The percentage of students assigned to teachers who said they used workbook/worksheets as the basis of their instruction was 34%, but 62% were assigned to teachers who use them as supplemental materials. The percentage of students assigned to teachers who said they used concrete objects or other materials as the basis for their instruction was 23% of students tested. Far more, 71%, were assigned to teachers who used them as supplemental materials. Teachers who reported using computer software as the basis for their instruction were assigned to 7% of students tested. A majority (55%) indicated using computer software as supplemental materials. Table 27 displays data as to resources teachers used in teaching mathematics.

Table 27

Resources Used by Responding Teachers to Teach Mathematics

	Textbooks		Workbooks/ Worksheets		Concrete Objects or Materials		Computer Software	
Country	Basis for Instruction	Supplement	Basis for Instruction	Supplement	Basis for Instruction	Supplement	Basis for Instruction	Supplement
Singapore	59%	38%	51%	48%	10%	85%	11%	82%
Republic of Korea	97%	3%	68%	32%	17%	77%	14%	69%
Japan	83%	15%	22%	75%	10%	80%	0%	27%
United States	48%	43%	19%	77%	17%	75%	14%	62%
International Average	77%	21%	34%	62%	23%	71%	7%	55%

Source. Mullis, Martin, Foy, & Arora (2012e).

Type of Instructional Activities in Every, or Almost Every, Lesson

The background study of the TIMSS focused on the types of instructional activities completed with every, or almost every lesson. Teachers reported using (a) work problems (individually or with peers) with teacher guidance, (b) work problems as a whole group with teacher guidance, (c) work problems (individually or with peers) while the teacher was occupied by other tasks, (d) memorize rules, procedures, and facts, (e) explain their answers, and (f) apply facts, concepts, and procedures. Results are reported in terms of the percentage of students tested assigned to teachers polled.

In Singapore, 41% of students tested worked problems with teacher guidance. The percentage of students who worked problems as a whole group was 40% of students tested. The percentage of students who worked problems while the teacher was occupied by other tasks was 8%. Students who memorized rules, procedures, and facts was 21% of students tested. The percentage of students who explained their answers was 30%. The percentage of students who applied facts, concepts, and procedures was 46% of students tested.

In the Republic of Korea, 67% of students tested worked problems with teacher guidance. The percentage of students who worked problems as a whole class was 77%. The percentage of students who worked problems while the teacher was occupied by other tasks was 45%. The percentage of students who memorized rules, procedures, and facts was 46%. The percentage of students who explained their answers was 21% of

students. The percentage of students who applied facts, concepts, and procedures was 68%.

In Japan, 65% of students worked problems with teacher guidance. The percentage of students who worked problems as a whole group was 49% of students tested. The percentage of students who worked problems while the teachers was occupied by other tasks was 9%. The percentage of students who memorized rules, procedures, and facts was 48%. The percentage of students who explained their answers was 24%. The percentage of students who applied facts, concepts, and procedures was 24% of all students tested.

In the United States, 75% of all students tested worked problems with teacher guidance. The percentage of students who worked problems as a whole group was 67%. The percentage of students who worked problems while the teacher was occupied by other tasks was 26%. The percentage of students who memorized rules, procedures, and facts was 23%. The percentage of students who explained their answers was 64%.. The percentage of students who applied facts, concepts, and procedures was 65%.

The international average of students who worked problems with teacher guidance was 55% of students tested. The percentage of students who worked problems as a whole group was 48%. The percentage of students who worked problems while the teacher was occupied by other tasks was 14%. The percentage of students who memorized rules, procedures, and facts was 45%. The percentage of students who explained their answers was 60%. The percentage of students who applied facts,

concepts, and procedures was 49%. Table 28 displays the percentage of students performing selected activities in every, or almost every, lesson.

Table 28

Percentages of Students Performing Selected Activities Every, or Almost Every Lesson

Country	Worked Problems (Individually or with Peers) with Teacher Guidance	Worked Problems Together in the Whole Class with Direct Teacher Guidance	Worked Problems (Individually or with Peers) While Teacher Occupied by Other Tasks	Memorize Rules, Procedures, and Facts	Explain Their Answers	Apply Facts, Concepts, and Procedures
Singapore	41%	40%	8%	21%	30%	46%
Republic of Korea	67%	77%	45%	46%	21%	68%
Japan	65%	49%	9%	48%	24%	24%
United States	75%	67%	26%	23%	64%	65%
International Average	55%	48%	14%	45%	60%	49%

Source. Mullis, Martin, Foy, & Arora (2012e).

The Availability of Computers for Mathematics Instruction

The background study also focused on the availability of computers for mathematics instruction. Results were reported in terms of the percentages of students who had and did not have computers available for mathematics lessons and the average achievement for those students. Also reported was the percentage of students whose teachers had them use computers at least monthly in the following ways: to explore

mathematics principles and concepts, to look up ideas and information, to process and analyze data, and to practice skills and procedures.

In Singapore, 56% of students had computers available for mathematics lessons. The average score of those students was 614. The average score for students who did not have computers available for lessons was 606. The percentage of students who used computers to explore mathematics principles and concepts was 38%. The percentage of students who used computers to look up ideas and information was 26%. The percentage of students who used computers to process and analyze data was 24%. The percentage of students who used computers to practice skills and procedures was 34%.

In the Republic of Korea, 56% of students had computers available for mathematics lessons. The average score for these students was 617. The average score for students who did not have computers available for lessons was 607. The percentage of students who used computers monthly to explore mathematics principles and concepts was 32%. The percentage of students who used computers to look up ideas and information was 30%. The percentage of students who used computers to process and analyze data was 25%. The percentage of students who used computers to practice skills and procedures was 28%.

In Japan, 58% of students had computers available for mathematics lessons. The average score of these students was 572. The average score for students who did not have computers available for lessons was 569. The percentage of students who used computers to explore mathematics principles and concepts was 3%. The percentage of students who used computers to look up ideas and information was 5%. The percentage

of students who used computers to process and analyze data was 6%. The percentage of students who used computers to practice skills and procedures was 1%.

In the United States, 44% of students had computers available for mathematics lessons. The average score of those students was 504. The average score for students who did not have computers available for lessons was 518. The percentage of students who used computers to explore mathematics principles and concepts was 25%. The percentage of students who used computers to look up ideas and information was 20%. The percentage of students who used computers to process and analyze data was 21%. The percentage of students who used computers to practice skills and procedures was 27%.

The international percentage of students who had computers available for mathematics lessons was 36%. The average score of these students was 470. The average score for students who did not have computers available for lessons was 467. The percentage of students who used computers to explore mathematics principles and concepts was 22%. The percentage of students who used computers to look up ideas and information was 23%. The percentage of students who used computers to process and analyze data was 21%. The percentage of students who used computers to practice skills and procedures was 24%. Table 29 contains teachers' perceptions as to the availability and usage of computers for mathematics lessons.

Table 29

Percentages of Students and Average Scores: Availability of Computers for Mathematics Lessons

Country	Computers Available for Mathematics Lessons			Percentage of Students Whose Teacher Have Them Use Computers At Least Monthly to:			
	% Students With Access	Average Score With Access	Average Score No Access	Explore Mathematics Principles and Concepts	Look Up Ideas and Information	Process Analyze Data	Practice Skills
Singapore	56%	614	606	38%	26%	24%	34%
Republic of Korea	56%	617	607	32%	30%	25%	28%
Japan	58%	572	569	3%	5%	6%	1%
United States	44%	504	518	25%	20%	21%	27%
International Average	36%	470	467	22%	23%	21%	24%

Source: Mullis, Martin, Foy, & Arora (2012e).

Time Spent on Mathematics Homework, Assessments, and Instruction

The background study addressed several aspects related to time and the study of mathematics. Teachers were queried as to the time spent on (a) homework, (b) assessments, and (c) instruction.

Time Spent on Homework

The background study also focused on how much time, in minutes, was spent on mathematics homework. Teachers were asked whether they assigned (a) three or more hours of homework, (b) more than 45 minutes but less than three hours, or (c) 45 minutes

or less of homework. Results were reported in terms of the percentage of students in each category and their average score.

In Singapore, 16% of students spent three or more hours of homework and had an average score of 628. A total of 57% of students spent more than 45 minutes but less than three hours on homework with an average score of 622. Students who spent 45 minutes or less on homework totaled 27% of students with an average score of 584.

In the Republic of Korea, 2% of students spent three or more hours of homework. The average score of these students was insignificant and was not included in the report. The percentage of students who spent at least 45 minutes but less than three hours on homework was 20% of students with an average score of 611. The percentage of students who spent 45 minutes or less on homework was 75% with an average score of 615.

In Japan, 3% of students spent three hours or more on homework with an average score of 586. The percentage of students who spent more than 45 minutes but less than three hours was 20% with an average score of 567. A total of 77% of students spent 45 minutes or less on homework and had an average score of 571.

In the United States, 15% of students spent three hours or more on homework with an average score of 535. Almost half, 43% of students spent more than 45 minutes but less than three hours on homework and had an average score of 519. Students who spent 45 minutes or less on homework totaled 43% with an average score of 496.

The international average of students who spent three or more hours on homework was 15%, and they had an average score of 464. Students who spent more

than 45 minutes but less than three hours on homework totaled 38% and had an average score of 478. Almost half, 48%, of students spent 45 minutes or less on homework and had an average score of 460. Table 30 contains the data regarding time spent, in minutes, on mathematics homework.

Table 30

Percentages of Students and Average Scores: Time Spent, in Minutes, on Mathematics Homework

	3 Hours or More		More Than 45 Minutes but Less Than 3 Hours		45 Minutes or Less	
Country	% Students	Average Score	% Students	Average Score	% Students	Average Score
Singapore	16	628	57	622	27	584
Republic of Korea	2	~ ~	20	611	75	615
Japan	3	586	20	567	77	571
United States	15	535	42	519	43	496
International Average	15	464	38	478	48	460

Source. Mullis, Martin, Foy, & Arora (2012b).

Time Spent on Mathematics Assessments

The amount of time spent on mathematics assessments was also studied as part of the TIMSS assessment. Teachers were polled as to how often they administered mathematics tests. Results were reported in terms of the percentages of students assigned to teachers in each category.

In Singapore, 39% of students tested were assigned to teachers who gave tests every two weeks or more. The percentage of students who were assigned to teachers who

gave tests about once a month was 51%. The percentage of students assigned to teachers who gave tests a few times a year was 10%.

In the Republic of Korea, 46% of students were assigned to teachers who gave tests every two weeks or more. The percentage of students assigned to teachers who gave tests about once a month was 42%. The percentage of students assigned to teachers who gave tests a few times a years was 12%.

In Japan, 15% of students were assigned to teachers who gave tests every two weeks or more. The percentage of students who were assigned to teachers who gave tests about once a month was 44%. The percentage of students assigned to teachers who gave tests a few times a year was 41%.

In the United States, 77% of students were assigned to teachers who gave tests every two weeks or more. The percentage of students assigned to teachers who gave tests about once a month was 22%. The percentage of students assigned to teachers who gave tests a few times a year was 1% of all students tested.

The international average of students who were assigned to teachers who gave tests every two weeks or more was 45% of students. The percentage of students assigned to teachers who gave tests about once a month was 40%. The percentage of students assigned to teachers who gave tests a few times a year was 15%. Table 31 contains the data as to time spent on mathematics assessment reported in terms of the percentages of students assigned to teachers in each category.

Table 31

Percentages of Students: Time Spent on Mathematics Assessment

Country	Percentage of Students Whose Teachers Give Mathematics Tests or Examinations		
	Every 2 Weeks or More	About Once A Month	A Few Times A Year
Singapore	39%	51%	10%
Republic of Korea	46%	42%	12%
Japan	15%	44%	41%
United States	77%	22%	1%
International Average	45%	40%	15%

Source. Mullis, Martin, Foy, & Arora (2012b).

Time Spent on Mathematics Instruction

A portion of the background study of the TIMSS focused on how much instructional time, in hours, was spent on mathematics instruction. Results were reported in terms of the number of hours of mathematics instruction per year and the total hours of all instruction per year.

In Singapore, a reported 138 hours were spent on mathematics instruction per year, and 1,106 hours were spent on total instruction per year. Thus, a total of 12.5% of instruction was spent on mathematics instruction per year in Singapore.

In the Republic of Korea, a reported 137 hours were spent on mathematics instruction per year, and 1,006 total hours were spent on total instruction per year.

Therefore, a total of 13.6% of total instructional time was spent in mathematics instruction in the Republic of Korea.

In Japan, a reported 108 hours were spent on mathematics instruction per year, and 1,016 hours were used for instruction in all subjects for the year. A total of 10.6% of total instructional time was used for mathematics instruction in Japan.

In the United States 157 hours were used for mathematics instruction per year, and 1,114 hours were used for all instruction per year. A total of 14% of total instructional time per year was used for mathematics instruction in the United States.

The international average hours used for mathematics was 138 hours per year, and a total of 1,031 hours were used for all instruction. Thus, the international average instructional time used for mathematics was 13.4% of total instructional time. Table 32 displays the instructional time, in hours, devoted to mathematics instruction and to total instruction in the four countries of interest in this study.

Table 32

Instructional Time, in Hours, Spent on Mathematics Instruction

Country	Hours of Mathematics Instruction Per Year	Total Hours of Instruction Per Year
Singapore	138	1,106
Republic of Korea	137	1,006
Japan	108	1,016
United States	157	1,114
International Average	138	1,031

Source. Mullis, Martin, Foy, & Arora (2012b).

The Percentage of Students Taught TIMSS Mathematics Topics

The percentage of students who were taught TIMSS mathematics topics was studied as part of the background questionnaire. Teachers were asked whether they taught all TIMSS topics (numbers, algebra, geometry, and data and chance). Results were reported in terms of the percentage of students tested who were taught the TIMMS mathematics topics at the time the assessment was administered.

In Singapore, 88% of students tested had been taught all 19 topics assessed by the TIMSS. Students who had been taught the five topics of numbers was 99% of students. The percentage of students who had been taught the five topics of algebra was 94% of students. The percentage of students who had been taught the six topics of geometry was 75% of students. The percentage of students who had been taught the three topics of data and chance was 83% of students tested.

In the Republic of Korea, 92% of students had been taught all 19 topics assessed. All of the students (100%) had been taught the five topics of numbers, and 91% had been taught the five topics of algebra. A total of 92% of students had been taught the six topics of geometry, and 81% of students had been taught the three topics of data and chance.

In Japan, 91% of students had been taught all 19 mathematics topics at the time of the test. In regard to numbers, teachers reported that 99% of students had been taught the five topics of numbers. The percentage of students who had been taught the five topics of algebra and the six topics of geometry were 92% and 93% respectively. The percentage of students who had been taught the three topics of data and chance was 75%.

In the United States, 90% of students had been taught all 19 mathematics topics assessed at the time of the assessment. The percentage of students who had been taught the five topics of numbers was 99%. The percentages of students who had been taught the five topics of algebra and the six topics of geometry were 86% and 87%, respectively. The percentage of students who had been taught the three topics of data and chance was 91% of students tested.

The international average of students who had been taught all 19 mathematics topics at the time of the assessment was 80%. The percentage of students who had been taught the five topics of numbers was 98%. The percentage of students who had been taught the five topics of algebra and the six topics of geometry were each 75%. The percentage of students who had been taught the three topics of data and chance was 66%. Table 33 indicates the percentages of participating students who teachers indicated were taught TIMSS mathematics topics in each of the four countries of interest in this study.

Table 33

Percentages of Participating Students Taught TIMSS Mathematics Topics

Country	All Topics (19)	Numbers (5)	Algebra (5)	Geometry (6)	Data and Chance (3)
Singapore	88%	99%	94%	75%	83%
Republic of Korea	92%	100%	91%	92%	81%
Japan	91%	99%	92%	93%	75%
United States	90%	99%	86%	87%	91%
International Average	80%	98%	75%	75%	66%

Source. Mullis, Martin, Foy, & Arora (2012b).

TIMSS Mathematics Topics Intended to be Taught by the End of Eighth Grade

The number of mathematics topics assessed by the TIMSS that were intended to be taught by teachers in participating countries was also part of the background study. Results were reported in terms of the number of topics intended to be taught to (a) all students, (b) only more able students, or (c) not intended to be taught. Table 34 displays the number of TIMSS mathematics topics intended to be taught by the end of eighth grade

Table 34

Number *of TIMSS Mathematics Topics Intended to be Taught by the End of Eighth Grade*

Topic (#)	Singapore	Republic of Korea	Japan	United States	International Average
All topics (19)					
All students	17	19	19	18	16
Only more able students	0	0	0	1	1
No intent to teach	2	0	0	0	2
Numbers (5)					
All students	5	5	5	5	5
Only more able students	0	0	0	0	0
No intent to teach	0	0	0	0	0
Algebra (5)					
All students	5	5	5	4	4
Only more able students	0	0	0	1	0
No intent to teach	0	0	0	0	1
Geometry (6)					
All students	5	6	6	6	5
Only more able students	0	0	0	0	0
No intent to teach	1	0	0	0	1
Data and chance (3)					
All students	2	3	3	3	2
Only more able students	0	0	0	0	0
No intent to teach	1	0	0	0	0*

Source. Mullis, Martin, Foy, & Arora (2012b). * indicates reporting error.

In Singapore, 17 of the 19 mathematics topics were intended to be taught to all students tested including all five numbers topics, the five algebra topics, five of six geometry topics, and two of three data and chance topics. One geometry topic and one data and chance topic were not intended to be taught by the end of eighth grade. In both the Republic of Korea and Japan, all 19 of the topics were intended to be taught by the

end of eighth grade. In the United States, 18 topics were intended to be taught by the end of eighth grade including all five numbers topics, four of five algebra topics, six geometry topics, and three data and chance topics. One of the five algebra topics was only intended to be taught to more able students by the end of eighth grade.

Internationally, 16 of the 19 TIMSS mathematics topics were intended to be taught to students by the end of eighth grade. This included five numbers topics, four of five algebra topics, five of six geometry topics, and two of three data and chance topics. One algebra topic and one geometry were not intended to be taught by the end of eighth grade. A reporting error, noted in one data and chance topic, was not intended to be taught by the end of eighth grade.

Legal Authority, Governance, and Finance of the Education System

Factors of student achievement concerning legal authority, governance, and finance of the public education systems in the sample countries included: the structure of governance in the public education systems, the levels of government at which decisions were made in making education policy such as graduation requirements, teacher required credentials, funding, curriculum guidance, and ensuring equal access to educational opportunity for all students. The structure of each public education system of the sample countries was analyzed, and the use of national curriculum standards within the countries of the sample were discussed along with the national assessments administered in the four countries. Finally, the impact and use of the TIMSS in public education systems in the countries in the sample were considered.

Policy, Governance, and Finance of Education

Policy, Governance, and Finance of Education in Singapore

Funding for education in Singapore has largely been provided by the national government. For funding purposes, schools in Singapore are classified into two groups: government schools and government aided schools. Government schools make up 76.5% of all schools in Singapore and are fully funded by the government. Government-aided schools include religious schools and other non-private schools specializing in merit based curriculum. These schools can be funded up to 90% by the government. The

unfunded portion of school costs are funded by parents of attending students through tuition and other school fees (Ministry of Education, Singapore, 2013).

Although the national government provides either full or partial funding for all schools in Singapore, the Ministry of Education collects school fees directly from parents up to $100 per month for the purpose of covering miscellaneous costs and "instilling a sense of importance of education" (Ministry of Education, Singapore, 2013) to parents. The government of Singapore provides monetary subsidies for low and middle income families who cannot afford school fees in a matrix of needs-based schemes.

In addition to regular per student allocation, the government provides $150 per student annually to seven independent/autonomous schools in Singapore. These schools are non-private and participate in merit-based enrollment. The additional funds are allocated to provide specialized resources for magnet type programming. Students from low to middle income families attending these schools are also eligible to receive government subsidized funds to cover school fees. The Ministry of Education has instituted a program to retrofit all schools in the nation built before 1997 with updated technological equipment and facilities.

Policy, Governance, and Finance of Education in the Republic of Korea

Funding for the education system in South Korea is largely provided by the national government which provides approximately 80% of the costs of education. The remaining 20% of costs are funded by local government, internal assets, locally funded bonds, school fees and tuition. National funds are paid directly to metropolitan and

provincial offices which oversee spending as each sees fit. These smaller offices located locally do not function as intergovernmental offices but rather as smaller branches of the same government. This practice is unlike that of the United States where educational funds come from three separate levels of government (federal, state, and local). Fees and day-to-day costs of operations, including teacher salaries, in South Korea are paid directly by the national governmental offices. Per student annual spending amounts to approximately $7,434 (adjusted to U.S. currency) and represents 7.6% of the national Gross Domestic Product (Ministry of Education, Science, and Technology, South Korea, 2013).

Policy, Governance, and Finance of Education in Japan

Policy, governance, and financing of the education system in Japan has been set by the national government and implemented through a combination of national, municipal, and local government offices. Unlike the United States, different levels of government do not act as separate entities. Rather, they function as local offices of the overall national government (MEXT, 2013).

The national government funds the education system totally with regard to necessary day-to-day operations. In addition to government funding, students in upper secondary school also pay school funds equating to approximately $100 per month. This extra funding is used to cover the expense of any "extra" costs schools may incur outside the government prevue of necessary expenditures. If school costs exceed the amount provided for by both the government and school fees, families must remit the difference.

The national government also supplements low income families up to $200 monthly for school fees.

Per student annual spending in Japan is approximately $8,250 (adjusted to U.S. currency) and represents 4.8% of the Gross Domestic Product. The majority of educational funding is used to provide for teachers and students. School buildings are functional but sparse. School administration teams are also extremely sparse compared to those in the United States, consisting of only a principal, assistant principal, one custodian, and one nurse per school (MEXT, 2013).

According to the Ministry of Education, the additional school fees required by families, and the sparse design of schools is purposeful and intended to instill a sense of importance to students and families. The purpose is to send a message that the government provides the cost of a high quality education, but the responsibility of that educations rests with the students and families. For example, instead of the government providing the costs of maintaining school cafeterias, students are selected to go to the school kitchens to pick up lunches and serve them to their teachers and peers in the classrooms and clean up afterwards. There are no costs incurred by the school for cafeteria monitors, custodians, or dishwashers. Those monies are shifted to instructional practices (MEXT, 2013).

Policy, Governance, and Finance of Education in the United States

Historically the United States has viewed the American education system as a service to its local communities. The United States constitution places the responsibility

of the education system solely with state governments. Although individual state and local governments fund the education systems in their states, the federal government provides supplemental funds in order to provide an element of equalization among states as well as strengthening state education systems by providing funding for supplemental education centers, educational research, and professional development for teachers. This practice was established with the 1965 implementation of the Elementary and Secondary Education Act, (ESEA). The No Child Left Behind Act, (NCLB) of 2001 was a reauthorization of the ESEA with the additional purpose of increasing the achievement levels of all students and decreasing the achievement gap among high and middle income students and economically disadvantaged students (Biddle & Berliner, 2002). Local property taxes have made up about half of educational funding. Approximately 33% of funding comes from the state government, and the remaining 17% comes from the federal government. As of 2005, total taxpayer contributions to the United States education system were reported to be $536 billion (Spelling, 2005). Federal education funding increased from 5.7% of the GDP in 1990 to 8.3% of the GDP in 2005. Total educational funding increased 105% from 1990 to 2004. This increase has been linked to the educational accountability movement in an effort to ensure the public is getting its money's worth, (Spelling, 2005). Between 2001 and 2006, federal funding increased $9.3 billion, 65% of which went to the funding of low income services and services provided by the Individuals with Disabilities Act. As of 2013, 95% of all federal education funds were reportedly being distributed directly to individual states and school districts, (ed.gov, 2013).

Because approximately half of education funding comes from local sources, a disparity has persisted between communities of middle and high incomes and those of low incomes. Biddle and Berliner, (2002) found, in their research that there were greater disparities in communities within states than there were among states. Table 35 contains information for funding disparities within states with the highest and lowest funding differences.

The policy, governance, and funding of the education systems in the three sample countries are very much the same. Differences occur in exact percentages of the gross domestic product funding the education system.

Table 35

Educational Funding Within States with the Greatest Funding Disparities

State	Per Student Annual Funding Between Counties
Alaska	$16,546 - $7,379
Vermont	$15,186 - $6,442
New Jersey	$13,709 - $8,401
New York	$13,749 - $8,518
Illinois	$11,507 - $5,260
Montana	$ 9,839 - $4,774
Nevada	$ 6,933 - $5,843
District of Columbia	No Disparity
Hawaii	No Disparity

As part of this study, the researcher examined the legal authority, governance, and financing of the education systems in each of the four sample countries participating in the 2011 administration of the TIMSS. Three of the four countries used a centralized education system. Only the United States had a decentralized education system. Three

of the four sample countries made the majority of educational policies at the national level of government. Only the United States made the majority of educational policies at the state level of government. The structure of the education systems in three of the four sample countries was stratified by student ability. Only the United States did not stratify the structure of its education system by the ability of students. Three of the four sample countries use national curriculum standards. At the time of this study, the United States had developed a national standard curriculum, but it had not been adopted or implemented by all states. Three of the four sample countries in this study used national assessments to measure the achievement of their students. At the time of this study the United States used state assessments to measure the achievement of its students.

All four of the sample countries reported that the TIMSS had an impact on their mathematics curriculum. Singapore reported its curriculum was designed around the TIMSS. Three of the four sample countries required a minimum of a bachelor's degree and a teaching certificate to become a teacher. Singapore required a minimum of a masters' degree and a teaching certificate to become a teacher.

The financing of the education systems of the four sample countries was diverse. In Singapore, the national government fully funded the education system. Parents were required to pay school fees in the amount of approximately $100 U.S. per month to instill a sense of importance in the education system. These funds were used to pay for miscellaneous school fees. In the Republic of Korea, the education system was funded by both the national government (80%) and local government (20%), internal assets, locally funded bonds, school fees, and tuition. In Japan, the national government fully

funded the education system. Parents were required to pay school fees in the amount of about $100 U.S. per month to instill a sense of importance in the education system. In the United States, the education system was funded by local government (50%), state government (33%), and national government (17%). Table 36 presents a comparative summary of the legal authority, governance and financial structure of the four countries that were the focus of this study.

Table 36

Comparative Summary: Legal Authority, Governance, and Finance of Education Systems

Descriptors	Singapore	Republic of Korea	Japan	United States
Form and degree of governance	Centralized	Centralized	Centralized	Decentralized
Level of government making educational policy	National	National	National	State
Structure of education systems	Stratified by ability level	Stratified by ability level	Stratified by ability level	Not stratified by ability level
Use of national curriculum standards	Yes	Yes	Yes	Not mandatory
Use of national assessments	Yes	Yes	Yes	No
Impact and use of TIMMS	National curriculum designed around TIMSS	National curriculum	National curriculum	State curriculum
Required teaching preparation and credentials	Masters' degree and teaching certificate	Bachelors' degree and teaching certificate	Bachelors' degree and teaching certificate	Bachelors' degree and teaching certificate
Information pertaining to funding of public education systems	Fully funded by national government; $100 school fees paid monthly by parents	80% funded by national government; 20% funded by local government, internal assets, locally funded bonds, school fees, and tuition	Fully funded by national government; $100 school fees paid monthly by parents	50% local government; 33% state government; 17% federal government

CHAPTER 5
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

This chapter contains a restatement of the purpose of the study and a summary and discussion of the findings as they relate to prior research. Also included in the chapter are conclusions, recommendations for practice, and recommendations for future research

Purpose of the Study

This study was conducted to analyze factors contributing to the rankings of top performing countries as measured by the eighth-grade mathematics scores of the Trends in International Mathematics and Science Study (TIMSS) examination. Factors that were examined for their similarities, if any, to determine their contribution to student achievement in the sample countries included: (a) student demographic information with regard to gender, socioeconomic status, student age, the total population of students in school, and total population of students participating in the assessment; (b) required credentials for educators; (c) mathematics curricula; (d) the authority, governance, and finance of the education systems.

In this study, students in the United States were compared to peers in other top performing countries; (Singapore, the Republic of Korea, and Japan). Factors were analyzed relating to school demographics, curriculum, teacher preparation, policy, and costs in global education systems. The information gained in this study was intended to

be used to influence decision making in the United States education system for the purpose of increasing student achievement in mathematics.

The 2011 Mathematics TIMSS Assessment was measured on a 1,000-point scale, though most students performed within the 300-700 point range. The centerpoint of the study was 500 points. Standard Deviations were set at each 100 point interval.

Summary and Discussion of the Findings

The following summary and discussion of the findings have been organized around the four research questions which were used to guide the study.

Research Question 1

What similarities, if any, existed in the student demographic information in the sample with regard to socioeconomic status, student age, gender, total population of students in school, and total population of students tested?

Student demographics revealed similarities in the way schools perceived their emphasis on student achievement. Most schools participating in the TIMSS believed they placed a high or very high emphasis on student achievement. All participating countries were above the international average in this area. Most schools in the sample countries also reported being either safe and orderly or somewhat safe and orderly. There were also similarities in student perceptions of bullying. In the sample countries, the majority of students perceived they were almost never bullied.

Major differences in the sample countries in the area of student demographics were with the location of participating schools by area population, school composition by student economic background, and students who spoke the language of the test at home.

A major difference in the area of student demographics was the percentages of students participating who lived in urban areas. The perceptions of urban populations is very different between eastern and western countries. In eastern countries the perception of urban populations is that of modern industrialization. More families of affluent means live in urban areas in Asian countries than in rural areas. In contrast, the perception of urban populations is very different in westerns countries like the United States. In the United States more affluent families live in suburban communities and urban populations are perceived as housing lower income families or families living in poverty. In both eastern and western countries families of lower income or families in poverty live in rural areas.

It is difficult to place an absolute definition on financial class systems between different countries. Kharas and Gertz (2010) give a general definition of financial class based on a country's Gross Domestic Product, (GDP). On average the lowest earners represent the lowest 20% GDP. The middle class represents between 20% - 80% of a nation's GDP. The most affluent class of population earns the top 80% of a nation's GDP. It is important to remember the types of areas in which participating students live and the financial means of families when looking at the reporting percentages of the study. The percentages of financial means of participating students' families suggests Singapore, the Republic of Korea, and Japan chose participating students who are more

advantaged than the average populations of those countries. The reported percentages in the United States suggests participating students who are less advantaged than the average population.

Singapore reported 100% of participating schools were located in urban areas where the population was more than 100,000 people. Similarly, the Republic of Korea reported that 87% of its participating schools were located in urban areas of more than 100,000 people, and Japan reported 67% of its participating schools were in areas of more than 100,000 people. In contrast, only 30% of participating schools in the United States were located in areas of more than 100,000 people.

The second major difference in student demographics was revealed in the following combined percentages of students attending more advantaged or medium income schools: Singapore, 88%; Republic of Korea, 69%; Japan, 90%; and the United States, 45%. The most significant difference in student demographics was the percentage of students attending schools comprised of more disadvantaged students: Japan indicated 10%; Singapore, 11%; and Republic of Korea, 32% of students attending schools comprised of more disadvantaged students. In contrast, the United States reported far more students (55%) as attending disadvantaged schools. These students scored below the TIMSS centerpoint at 490 points.

Research Question 2

What similarities, if any, existed in the required credentials for educators in the sample in regard to degrees earned, certification requirements, professional development, and collaboration with peers?

Research Question 2, regarding factors pertaining to required teaching credentials, revealed many similarities between the sample countries. Although Singapore and Japan reported 2% and 1% respectively of their students were assigned to teachers who had completed post-secondary school but not a bachelor's degree, the overwhelming majority of teachers had at least a bachelor's degree. At 62%, the United States had the highest percentage of students assigned to teachers with advanced degrees. The Republic of Korea has the next highest percentage with 37%. Singapore reported 10%, and Japan reported 9% of students assigned to teachers with advanced degrees.

There were significant variances in major areas of study completed by teachers in the sample countries. In Singapore, the majority of students were assigned to teachers who majored in mathematics but not primary education. In the Republic of Korea, the majority of students were assigned to teachers who majored in primary education but not mathematics. In both Japan and the United States the majority of students were assigned to teachers who majored in both mathematics and primary education.

Another similarity between sample countries was teachers' average years of experience. The Republic of Korea, Japan, and the United States reported teachers' average years of experience ranged between 13-17 years. The average for all

international teachers was 16 years. Singapore reported a national average of only eight years of experience for its teachers.

There were significant variances in the percentages of participation in professional development between the sample countries. The majority of students were assigned to teachers who participated in either mathematics content or mathematics pedagogy professional development. The United States had the highest reported percentages of students assigned to teachers who participated in all areas of professional development with the exception of mathematics pedagogy. Singapore reported 79% of its students were assigned to teachers participating in this area of professional development, but the United States reported only 73% of its students were assigned to teachers who had benefited from professional development in mathematics pedagogy.

With regard to teacher preparedness to teach the 19 overall TIMSS mathematics topics, only Japan reported well below the international average of 84%. In all of the sample countries, teacher confidence in teaching specific mathematics topics was listed in descending order as follows: numbers, algebra, geometry, and data and chance. Teachers in the United States had the highest reported percentage of students assigned to teachers who believed they were very well prepared to teach the TIMSS mathematics topics.

Regarding the percentage of students assigned to teachers who felt very confident in teaching mathematics, only the United States reported percentages higher than the international average of 76%. Singapore, the Republic of Korea, and Japan all reported percentages well below the international average. The United States reported 86% of students were assigned to teachers who felt very confident in teaching mathematics. The

United States also had the highest percentages reported of students assigned to teachers who felt very confident in answering students' questions about mathematics.

In considering teachers' career satisfaction, the United States reported the highest percentage of students assigned to participating teachers who were satisfied with their teaching careers. In Singapore, the Republic of Korea, and Japan there was a significant difference in the degree of teacher career satisfaction and the level of student achievement. In the United States there was no significant difference in student achievement between teachers with varying degrees of career satisfaction.

Regarding the level of collaboration among teachers, teachers in the United States reported the highest percentage of students assigned to teachers who were very collaborative with their peers. The international average of students assigned to teachers who were reported as very collaborative with their peers was 28%. The United States reported 39% of students were assigned to very collaborative teachers. Singapore, the Republic of Korea, and Japan reported only 15%-17% of students were assigned to very collaborative teachers.

Research Question 3

What similarities, if any, existed in mathematics curriculum in the sample with regard to the order of instruction, educational pedagogy, and delivery models?

Though numerous mathematics curriculum and instruction similarities were found among the sample countries, only the United States reported teachers using instructional practices to engage students in learning mathematics in most lessons above the

international average of 80%. The United States reported 93% of students were assigned to teachers who use instructional practices to engage students in most lessons. Singapore only reported 63% of students, the Republic of Korea reported 65% of students, and Japan reported 55% of students as being assigned to teachers who used instructional practices to engage students in most lessons.

Regarding teachers relating lessons to students' lives, the United States was again the only sample country scoring above the international average of 39%. In the United States, 40% of students were assigned to teachers who related lessons to students' lives for almost every lesson. Singapore, the Republic of Korea, and Japan reported 16%, 21%, and 10% of students, respectively, as relating lessons to students' lives for almost every lesson.

The United States also reported the highest percentage (29%) of students assigned to teachers who said much instructional time was lost due to students' lack of nutrition. Singapore (14%), the Republic of Korea (18%), and Japan (6%) all reported percentages lower than the international average of 28%.

The United States also reported the highest percentage (78%) of students assigned to teachers who reported much instructional time lost due to students' lack of sleep. Singapore, the Republic of Korea, and Japan reported students, 69%, 63%, and 34% respectively, as having been assigned to teachers who reported much instructional time lost due to lack of sleep.

In considering the issue of much instructional time being lost due to disruptive students, the Republic of Korea reported the largest percentage of students at 40%. The

international average of students who were assigned to teachers who reported much loss of instruction due to disruptive students was 17% of students. The United States reported 14%, Japan reported 1%, and Singapore reported 12% in this regard.

As to the issue of much instructional time being lost due to uninterested students, the Republic of Korea reported the highest percentage of students at 29%. The international average in this area was 24%. The United States reported 19% of its students were assigned to teachers who reported much instructional time lost due to uninterested students. Japan reported 4% of students, and Singapore reported 13% of students in this area.

The types of materials used for instruction (textbooks, workbooks, concrete objects, and computer software) were also considered in responding to this research question. Singapore, the Republic of Korea, and Japan reported most teachers used textbooks as their basis of instruction with workbooks, concrete objects, and computer software used as supplemental material. The United States reported a more divergent use of materials and resources beyond textbooks as the basis of instruction.

Another area of investigation was students' participation in instructional activities in almost every lesson (working problems individually or in peer groups, working problems as a whole group or small groups, working problems while the teacher is engaged in other tasks, memorizing rules, explaining their answers, and applying facts and concepts). The United States reported the highest percentages of the sample countries in all areas except two: (a) working problems while the teacher is engaged in other tasks and (b) memorizing rules. All four of the sample countries reported higher

percentages than the international average in the availability of computers for student use in mathematics classrooms.

Research Question 4

What similarities, if any, existed in the policies, governance, and finance of the education systems in the sample with regard to the levels of government making educational policy, landmark legislation in education, the structure of educational systems, the use of national curriculum standards, the use of national assessments, and information pertaining to the funding of public education systems?

The comparisons examined to answer this research question led to the least number of similarities for the United States with the sample countries being studied. In Singapore, the Republic of Korea, and Japan, the national governments were revealed to have control over centralized education systems. The national government of these countries made the majority of funding and policy making decisions. Only in the United States was the education system decentralized with the majority of power in financing and policy making controlled at the state level. Although Singapore, the Republic of Korea, and Japan each had a single unified education system, the United States operated with 50 education systems that functioned largely independently.

Another difference found in the study was the structure of the U.S. education systems as compared with the sample countries' systems. In Singapore, the Republic of Korea, and Japan, the structure of the system was stratified by student ability. Students in these countries completed homogeneous courses through fourth grade. At the end of

fourth grade, students were assessed and placed in classes according to their ability for the remainder of their compulsory education. Students were allowed to complete coursework and progress forward to more advanced classes. In the United States all students completed coursework addressing the same standards. There were variances, however, in courses that addressed the same standards at differing levels of mastery.

Three of the four sample countries used national curriculum standards. At the time of this study, the United States had developed a national standard curriculum, but it had not been adopted or implemented by all states. Three of the four sample countries in this study used national assessments to measure the achievement of their students. At the time of this study the United States used state assessments to measure the achievement of its students.

All four of the sample countries reported that the TIMSS had an impact on their mathematics curriculum. Singapore reported its curriculum was designed around the TIMSS. Three of the four sample countries required a minimum of a bachelor's degree and a teaching certificate to become a teacher. Only Singapore required a minimum of a masters' degree and a teaching certificate to become a teacher.

The financing of the education systems of the four sample countries was diverse. In Singapore, the Republic of Korea, and Japan, the national government funded most, if not all, of the respective education systems. Parents in each of these countries were expected to pay monthly school fees in order to instill a sense of importance in the education systems. Although there were variances among the states, in the United States,

the education system was funded on average by local government (50%), state government (33%), and national government (17%).

Conclusions

Although similarities were found to exist among the sample countries in the areas of teacher preparation and curriculum and instruction, it should be noted that the United States provided the initial constructs and, in a sense, served as a model for the other sample countries. Singapore, the Republic of Korea, and Japan modeled their education systems after those already established in the United States and Great Britain which either occupied or colonized these countries as early 1775 with the opening of Japan to western society (Mikami & Smith 1914). Having followed the models of other countries, Singapore, the Republic of Korea, and Japan were able to implement the best parts of those systems and avoid mistakes made during the prior efforts of established countries.

Major differences in student achievement among the sample countries are due to two major constructs: (a) the size, population, and form of government in each of the countries and (b) the types of students chosen to participate in the TIMSS. It is around these characteristics that conclusions were drawn for this study.

One conclusion that can be drawn from this study is that size does matter. The size and population of the country does correspond with student achievement. For example, Singapore, the smallest of the sample countries, reported one of the highest student achievement. Due to the small size of the country, the government has been able to closely monitor the education system. Due to the more homogenous nature of the

population (race, socioeconomic status, and percentage of urban population), the government has been able to put in place policies in curriculum and instruction that have more of a "best fit for all" quality. Japan, the largest of the three Asian sample countries, reported student achievement scores much more comparable to those of the United States. The population of students tested in Japan were also more diverse than those of Singapore and Republic of Korea.

Also, due to its small size, homogenous population, and centralized education system, Singapore was able to provide equal resources to all schools. There are 50 governing bodies of the education system in the United States, each with its own matrices on how education should be funded. Each local government within those 50 has its own allotment for education resources. For example the availability of computers used for instruction in every classroom is markedly different in the centrally funded countries than in the United States.

A second major area of difference among the sample countries is the population of students chosen to participate in the TIMSS. In the three Asian sample countries, student demographic information showed the best and brightest of the countries were chosen to participate in the assessment. For example, in Singapore, 100% of students participating in the TIMSS lived in urban settings. It is important to note the perception of "urbanization" in Asian countries is quite different to that in the United States. In Asian countries urban centers are symbols of modernity, industrialization, and wealth. In contradiction, the perception of schools in urban settings is that of low achievement and poverty. In the United States, only 30% of participating students lived in an urban setting.

In addition to living in areas where school resources were plentiful, another contributing factor in differences of student achievement had to do with the socioeconomic levels of the students' families. In Singapore, 89% of students were either from high or medium income homes, and only11% of participating students were from low income families. By contrast in the United States, only 45% of participating students were from high and medium income families, and 55% of students participating in the TIMSS were from low income families. The teachers of these students also reported major disruption of instruction by students' lack of sleep and lack of nutrition among other factors indicative of students from low income families. It seems there is a major difference in the types of students chosen to participate in the TIMSS. Where other countries put forth the best and brightest students they have to offer, the United States seems to have selected students from demographic areas that have traditionally been underachieving. When researching exactly how students were selected to participate in any of the participating countries, no satisfactory answer could be found in any resources provided by TIMSS.

Recommendations for Practice

One piece of data, not made available by TIMSS, was the specific school districts in the United States that participated in the assessment. Location of benchmarking testing and participating students was made available by state but not by school district. For the actual assessment, i.e., student achievement scores used in the global rankings, participant location information was not made available. Due to the differences in school

districts across the United States, it is recommended that the location of participating students should be transparent.

To provide a more equitable comparison, it is the recommendation of the researcher that student achievement should be measured among students using the same demographic parameters as other top performing countries. For example, the United States and the Asian countries in this sample should use the same percentages of students living in urban areas and from high or medium income families.

A final note is the observation that in Singapore it is required by the government that all teachers must have earned a master's degree as shown in Table 36. However, when teachers self- reported their highest earned level of education, teachers in Singapore reported only 10% earned a graduate degree as shown in Table 8.

Recommendations for Future Research

Due to each of the 50 states in the U.S. governing its own education system, one implication for further research would be to conduct this study within the 50 states. Because the United States is moving in the direction of a nationalized curriculum, but has not unanimously adopted or implemented such, it would be interesting to compare student achievement in mathematics among the 50 states. It would also be valuable to conduct a study of students with similar backgrounds (student location and socioeconomic level) both within the United States and Internationally.

APPENDIX A
COUNTRIES PARTICIPATING IN TIMSS 2011 AND IN EARLIER TIMSS ASSESSMENTS

Countries Participating in TIMSS 2011 and in Earlier TIMSS Assessments

Country	Grade 4				Grade 8				
	2011	2007	2003	1995	2011	2007	2003	1999	1995
Armenia	●	○	●		●	○	●		
Australia	●	●	●	●	●	●	●	○	●
Austria	●	●		●					●
Azerbaijan	●								
Bahrain	●				●	●	●		
Belgium (Flemish)	●		●				●	●	●
Botswana						●	●		
Chile	●				●		●	●	
Chinese Taipei	●	●	●		●	●	●	●	
Croatia	●								
Czech Republic	●	●		●		●		●	●
Denmark	●	●							●
England	●	●	●	●	●	●	●	●	●
[1] Finland	●				●			○	
Georgia	●	●			●	●			
Germany	●	●							●
Ghana					●	●	●		
Hong Kong SAR	●	●	●	●	●	●	●	●	●
Hungary	●	●	●	●	●	●	●	●	●
Indonesia				○	●	●	○	○	○
Iran, Islamic Rep. of	●	●	●	●	●	●	●	●	●
Ireland	●			●					●
Israel				●	●	○	○	○	○
Italy	●	●	●	○	●	●	●	●	○
Japan	●	●	●	●	●	●	●	●	●
Jordan					●	●	●	●	
Kazakhstan	●	○			●				
Korea, Rep. of	●			●	●	●	●	●	●
Kuwait	●	○		○		○			○
Lebanon					●	●	●		
Lithuania	●	●	●		●	●	●	●	●
Macedonia, Rep. of					●		●	●	
Malaysia					●	●	●	●	
Malta	●					●			
Morocco	●	●	●		●	○	○	○	

SOURCE: IEA's Trends in International Mathematics and Science Study – TIMSS 2011

Netherlands	●	●	●	●			●	●	●
New Zealand	●	●	●	●	●		●	●	●
Northern Ireland	●								
Norway	●	●	●	●	●	●	●		●
Oman	●				●	●			
Palestinian Nat'l Auth.					●	●	●		
Poland	●								
Portugal	●			●					●
Qatar	●	○			●	○			
Romania	●				●	●	●	●	●
Russian Federation	●	●	●		●	●	●	●	●
Saudi Arabia	●				●	○	○		
Serbia	●					●	●		
Singapore	●	●	●	●	●	●	●	●	●
Slovak Republic	●	●					●	●	●
Slovenia	●	●	●	●	●	●	●	○	●
South Africa							●	●	○
Spain	●								●
Sweden	●	●			●	●	●		●
Syrian Arab Republic					●	●	○		
Thailand	●			○	●	●		●	○
Tunisia	●	●	●		●	●	●	●	
Turkey	●				●	○		○	
Ukraine		●			●	●			
United Arab Emirates	●				●				
United States	●	●	●	●	●	●	●	●	●
Yemen	●	●	○						

● Indicates participation in that testing cycle.

○ Indicates participation but data not comparable for measuring trends to 2011, primarily due to countries improving translations or increasing population coverage.

1 Finland assessed their fourth and eighth grade students in 2011. Also, to measure trends from their 1999 seventh grade results, Finland assessed their seventh grade students in 2011 as well.

Country	Grade 4				Grade 8				
	2011	2007	2003	1995	2011	2007	2003	1999	1995
Out of Grade Participants									
Botswana (6,9)	●				●				
Honduras (6,9)	●				●				
South Africa (9)					●				
Yemen (6)	●								
Benchmarking Participants									
Alberta, Canada	●	●		●	●			●	●
Ontario, Canada	●	●	●	●	●	●	●	●	●
Quebec, Canada	●	●	●	●	●	●	●	●	●
Abu Dhabi, UAE	●				●				
Dubai, UAE	●	●			●	●			
Alabama, US					●				
California, US					●				
Colorado, US				●	●				
Connecticut, US					●			●	
Florida, US	●				●				
Indiana, US			●		●		●	●	
Massachusetts, US		●			●	●		●	
Minnesota, US		●		●	●	●			●
North Carolina, US	●				●			●	

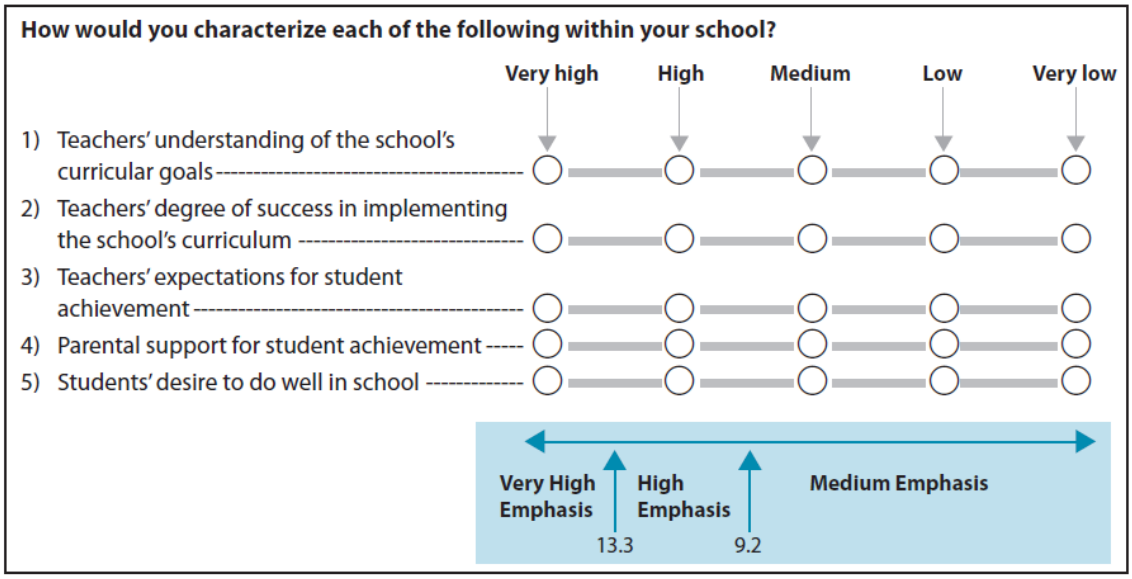
● Indicates participation in that testing cycle.

○ Indicates participation but data not comparable for measuring trends to 2011, primarily due to countries improving translations or increasing population coverage.

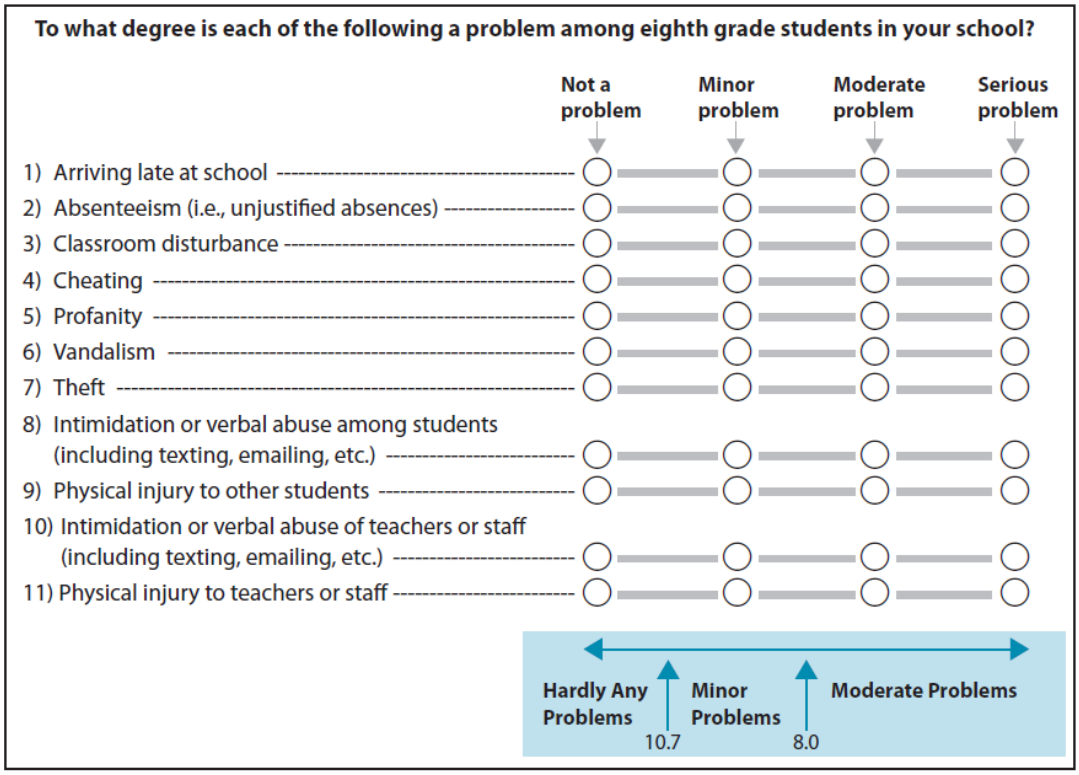
SOURCE: IEA's Trends in International Mathematics and Science Study – TIMSS 2011

APPENDIX B
TIMSS QUESTIONNAIRE ITEMS

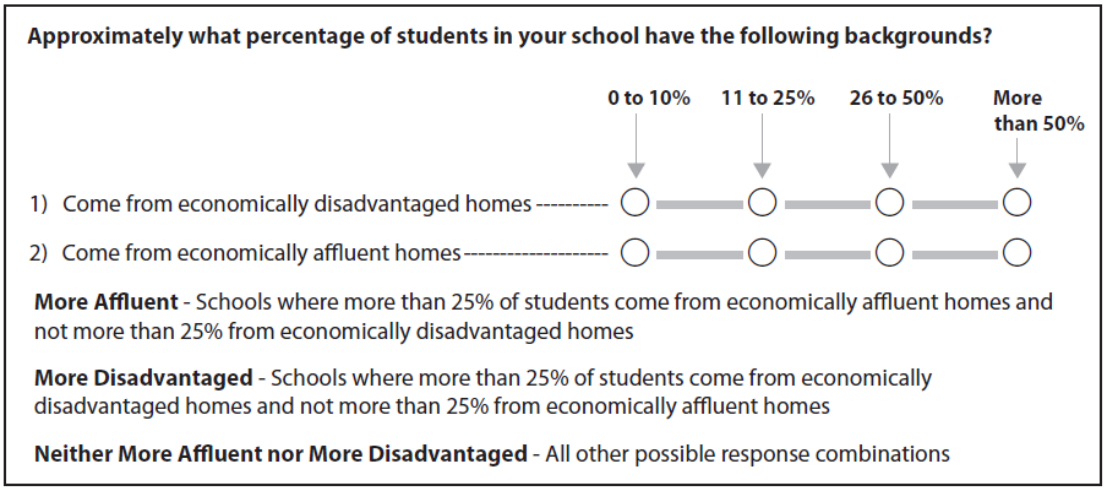
Principals' emphasis on academic achievement



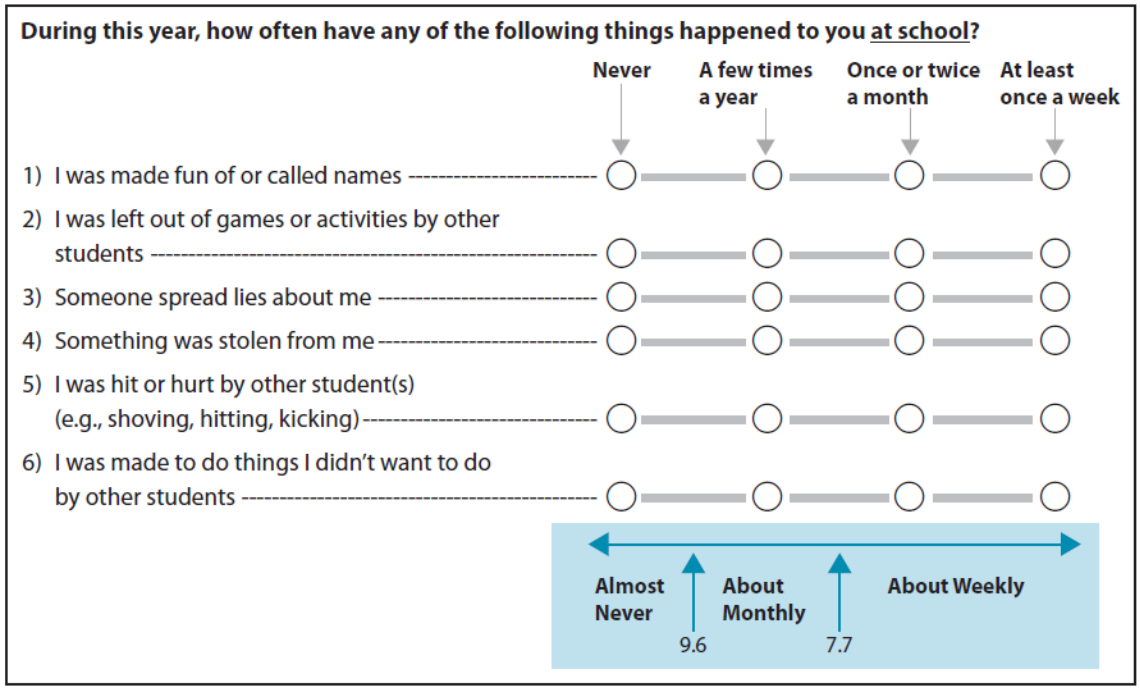
Degree of Disciplinary Issues



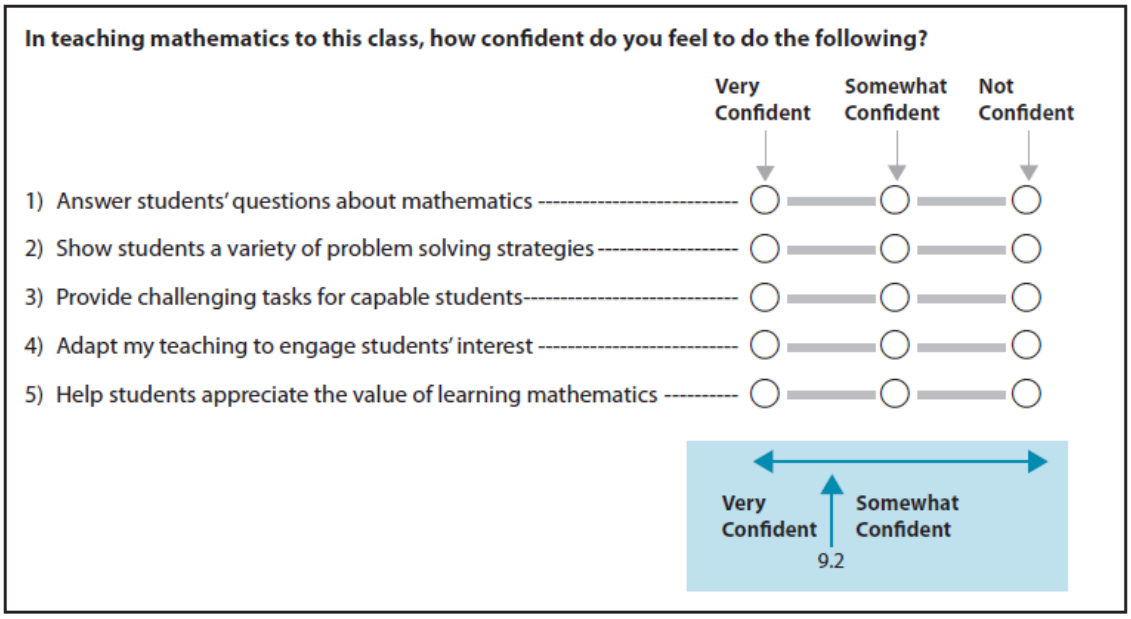
Question regarding socioeconomic background



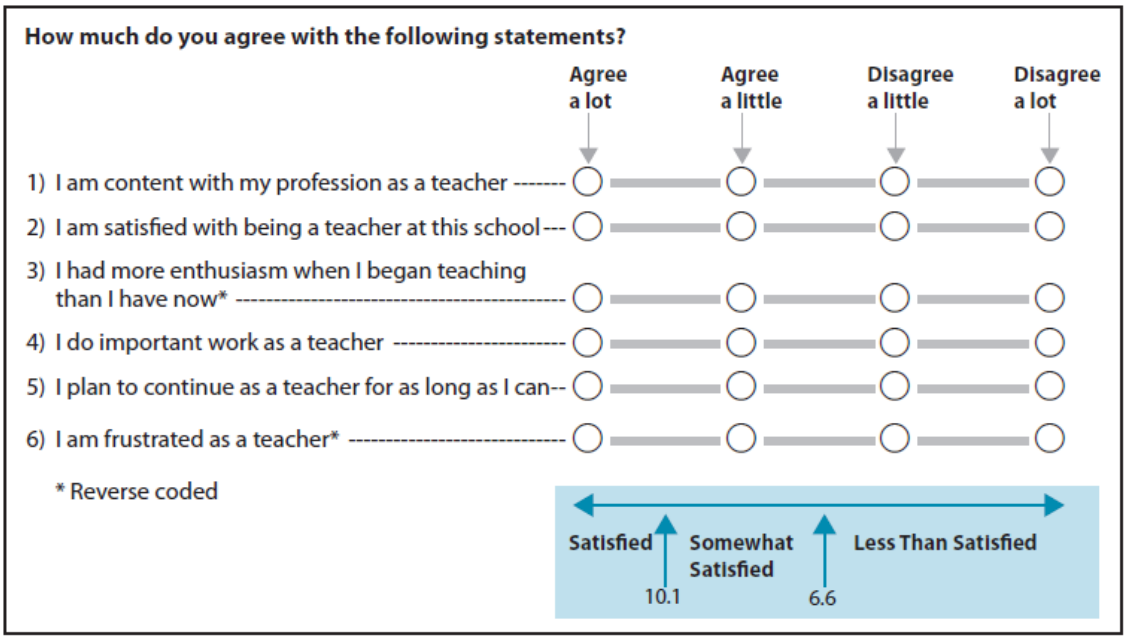
Degree of student perception of bullying



Teacher items regarding confidence in teaching



Teacher levels of satisfaction



TIMSS 2011 Mathematics Topics

A. Number

1) Computing, estimating, or approximating with whole numbers
2) Concepts of fractions and computing with fractions
3) Concepts of decimals and computing with decimals
4) Representing, comparing, ordering, and computing with integers
5) Problem solving involving percents and proportions

B. Algebra

1) Numeric, algebraic, and geometric patterns or sequences
2) Simplifying and evaluating algebraic expressions
3) Simple linear equations and inequalities
4) Simultaneous (two variables) equations
5) Representation of functions as ordered pairs, tables, graphs, words, or equations

C. Geometry

1) Geometric properties of angles and geometric shapes
2) Congruent figures and similar triangles
3) Relationship between three-dimensional shapes and their two-dimensional representations
4) Using appropriate measurement formulas for perimeters, circumferences, areas, surface areas, and volumes
5) Points on the Cartesian plane
6) Translation, reflection, and rotation

D. Data and Chance

1) Reading and displaying data using tables, pictographs, bar graphs, pie charts, and line graphs
2) Interpreting data sets
3) Judging, predicting, and determining the chances of possible outcomes

A. How often does your teacher give you homework in mathematics?

1) Every day
2) 3 or 4 times a week
3) 1 or 2 times a week
4) Less than once a week
5) Never

B. When your teacher gives you mathematics homework, about how many minutes do you usually spend on your homework?

1) My teacher never gives me homework
2) 1-15 minutes
3) 16-30 minutes
4) 31-60 minutes
5) 61-90 minutes
6) More than 90 minutes

The weekly time spent on mathematics homework was calculated by multiplying how often students were given homework weekly by the minutes they spent on that homework.

The values for Part A were: Every day = 5; 3 or 4 times a week = 3.5; 1 or 2 times a week = 1.5; Less than once a week = 0.5; and Never = 0.

The values for Part B were: My teacher never gives me homework = 0; 1-15 minutes = 8; 16-30 minutes = 23; 31-60 minutes = 45; 61-90 minutes = 75; and More than 90 minutes = 105.

Source: *International Mathematical and Science Study*, *TIMSS 2011* by I.V.S. Mullis, M. O. Martin, P. Foy, & A. Arora. (2012). Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

APPENDIX C
TEMPLATES USED IN DATA COLLECTION

Template for Collection of Data: Student Demographic Information

Descriptor	Singapore	The Republic of Korea	Japan	The United States
Principal and teacher emphasis on academic achievement				
Degree of disciplinary problems, safety and orderliness				
Location of school in regards to area population				
Family socioeconomic status within the School				
Students assessed in native language				
Student perception of bullying				

Template for Collection of Data: Teacher Preparation and Required Credentials

Descriptors	Singapore	The Republic of Korea	Japan	The United States
Teacher levels of post-secondary education				
Teacher major area of study in college				
Teacher years of experience				
Teacher participation in professional development in mathematics				
Teacher level of preparedness in teaching mathematics topics assessed by TIMSS				
Teacher degree of confidence in teaching mathematics				
Teacher degree of confidence in specific components of teaching mathematics				
Teacher level of collaboration with peers				
Level of teacher satisfaction with career				

Template for Collection of Data: Legal Authority, Governance, and Finance of the Education System

Descriptor	Singapore	The Republic of Korea	Japan	The United States
Form and degree of governance				
Level of government making educational policy				
Landmark legislation in education				
Structure of education systems				
Use of national curriculum standards				
Use of national assessments				
Impact and use of TIMMS				
Required teaching preparation and credentials				
Information pertaining to funding of public education systems				

Template for Collection of Data: Mathematics Curriculum and Instruction

Descriptors	Singapore	The Republic of Korea	Japan	The United States
Number of TIMSS mathematics topics intended to be taught by the end of eighth grade				
How much instructional time, in minutes, is spent on mathematics instruction				
Percentage of participating students taught TIMSS mathematics topics				
How often teachers use instructional practices to engage students in learning mathematics				
How often teachers relate lessons to students' daily lives and bring interesting material to class				
How much instructional time is limited by students lacking prerequisite knowledge or skills				
How much instructional time is limited by students suffering from lack of nutrition or sleep				
How much instructional time is limited by disruptive or uninterested students				
Resources used by teachers to teach mathematics				
Instructional strategies used in every, or almost every lesson				
The availability of computers for mathematics lessons				
How often students are assessed in mathematics in the classroom				
How much time, in minutes, is spent on mathematics homework				
Landmark theories of instructional pedagogy				
Delivery model most used in the instruction of mathematics				
Information on the order of instruction of mathematics curriculum				

APPENDIX D
INSTITUTIONAL REVIEW BOARD APPROVAL

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901, 407-882-2012 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

From : **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To : **Courtney Wilson** and Co-PIs: **Barbara A. Murray**

Date : **September 06, 2013**

Dear Researcher:

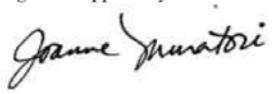
On 9/6/2013, the IRB determined that the following proposed activity is not human research as defined by DHHS regulations at 45 CFR 46 or FDA regulations at 21 CFR 50/56:

Type of Review:	Not Human Research Determination
Project Title:	A Comparative Analysis of Eighth Grade Mathematics Scores of Top Performing Countries
Investigator:	Courtney Wilson
IRB ID:	SBE-13-09584
Funding Agency:	
Grant Title:	
Research ID:	N/A

University of Central Florida IRB review and approval is not required. This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are to be made and there are questions about whether these activities are research involving human subjects, please contact the IRB office to discuss the proposed changes.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Joanne Muratori on 09/06/2013 02:05:09 PM EDT



IRB Coordinator

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